Higher Education, Innovation and Economic Development

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Paper to be presented at the World Bank's Regional Bank Conference on Development Economics, Beijing, January 16-17, 2007.

Abstract

This paper links higher education to economic development through an analysis of how graduates contribute to innovation and learning and it draws policy implications for economic development. The starting points are two original contributions to the understanding of the role of higher education in relation to economic change (Nelson and Phelps 1965; Schultz 1979). On this basis we move ahead and referring to recent empirical research we demonstrate that graduates act both as *innovators* and *equilibrators* in what we call the *learning economy*.

We end the analytical part concluding that investment in higher education may not give substantial rates of return in a technologically stagnant economy. Since the alternative to invest in higher education is to remain in stagnation forever, we focus our policy discussion on two questions. First, how to design higher education in such a way that it helps to break the vicious circle of stagnation and stagnating demand for graduates? Second, how to design a general strategy for vitalising national innovation systems that includes investment in higher education as important element?

We recommend less developed countries to build universities more strongly rooted in the regional context – a model referred to in the paper is the US land grant college including its extension services. We also recommend deep reform of teaching methods establishing stronger emphasis on problem-based learning, where problems are taken from the domestic reality, as well as integration of local practical experience in study programs. Such reforms should be used to strengthen the third mission. Without reform and with focus on building universities as national centres of excellence the major outcome of investments may be further brain-drain toward the rich countries.

We end arguing that reforms of higher education cannot alone break vicious circles. There is a need for ambitious national strategies aiming at vitalising the innovation system. Reforming higher education should be seen as a key element of such a strategy.

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> *It is absurd to think that we can derive the contour lines of our phenomena from our statistical material only. All we could ever prove from it is that no regular contour lines exist……. We cannot stress this point sufficiently. General history (social, political and cultural), economic history and industrial history are not only indispensable, but really the most important contributors to the understanding of our problem. All other materials and methods, statistical and theoretical, are only subservient to them and worthless without them. (Schumpeter 1939)*

Introduction[1]

In the US, the richest country in the world, more than 90% of a cohort joins higher education. In Burkina Faso, one of the poorest countries in the world, only one out of hundred young people gets access to higher education. Does it follow that Burkina Faso would get better off by investing more in higher education? Or is it the other way around that the low frequency of education reflects the extreme poverty in the country? As we shall see, bringing innovation and learning into the picture may help understanding the mechanisms at play.

[1] While working on this paper I have benefited from interaction with Judith Sutz, Edward Lorenz, Rene Nesgaard Nielsen, Keynor Ruiz, Mammo Muchie and Claes Brundenius. Most important have been critical and constructive comments from Shulin Gu. But, of course, I take full responsibility for the draft as it stands now. Some critical reader may note that most of the empirical material comes from Denmark/Europe while an attempt is made to deraw conclusions for less developed countries. To some degree this reflects that the kind of data used are not acessible for the less developed part of the world. But it also reflects my background and my use of data-rich Denmark as laboratory.

Graduates[2] normally have a higher salary than non-graduates and this is by economists taken as an expression for higher (marginal) productivity. Why are graduates more productive than non-graduates? What functions can a graduate execute better than non-graduates? What competences attained in the education system make the graduate more efficient? Which are the competences required in the current era of rapid change? Are the required competences the same in a poor country as in a rich country? What are the implications for the organisation and teaching methods of higher education? Again, bringing innovation and learning into the picture helps understanding the mechanisms at play.

This paper introduces new perspectives on higher education by relating it to innovation and learning and draws some preliminary policy conclusions for developed and less developed countries. But the specificity of the recommendations is limited and they are so for good reasons. One reason is that we know far too little about what graduates actually contribute to economy and society in less developed countries and much more research is needed on this topic. There is a need to open up the 'black box' inside which graduates use their skills and competences. Here we can only offer a first glimpse.

The other reason is that both the challenges and the required solutions differ widely across the world. While almost all countries in the South and East have introduced 'universities' inspired by western models the context in which they operate are fundamentally different and so is the form and content of what goes under the label 'university' (Altbach 1989; Martin and Etzkowitz 2000). Such differences may reflect the income level. But the size of the country matters and so does the

[2] In this paper, to simplify, we will refer to the sites of higher education as 'universities' and to those that leave the system with full education as 'graduates'. We do so well aware that there are forms of higher education, including professional schools without connection to research activities, where this terminology may be misleading.

combination of history and geography. The colonial history of the Latin American, Asian and African countries has put its stamp on how higher education is organised on these continents.

To give full justice to such diversity and complexity is of course not possible in a brief paper. To design adequate policy there is a need to combine general principles and insights with a deep and thorough analysis of the specific higher education system and its insertion in the national innovation system. While statistics showing numbers of graduates distributed on disciplines may be of some relevance it is necessary to dig much deeper into the complex reality hidden behind such figures (cf. the introductory methodological advice stemming from Schumpeter).

Graduates as equilibrators and innovators

In this section we will present models and empirical analyses that give general insight in the roles that graduates play in the economy. We start by two classical contributions and move on to bring innovation and learning centrally into the analysis.

Two attempts to explain why higher education contributes to economic growth

Policy makers with responsibility for higher education need to find arguments to convince ministries of finance to use scarce public money for higher education. The most usual approach has been to look for social rates of return higher than private rates of return. That kind of analysis has sometimes shown results that support investment in higher education but not always.[3] The problem with this approach is not only that it neglects social, cultural and health benefits not reflected in wage differences: It is highly questionable if the basic assumptions that lie behind the analysis (that agents are optimising and that wages are equal to marginal productivity) are consistent with the fact

[3] Pritchett (2001), using aggregate data for national economies, comes out with very negative results in this respect showing that investment in education, in general, has no positive effect on economic growth – in some national cases he even finds a negative impact. But he also refers to a few studies showing that the impact of the *quality* of education has a major impact on growth. We will return to the 'quality issue' later on in this paper.

that we live in a rapidly changing world characterised by disequilibria and radical fundamental uncertainty. And as argued below disequilibria and uncertainty are key factors when it comes to determine the usefulness of graduates in the economy.

Compared to the numerous attempts to calculate rates of return few economists have asked the more down to earth question: Why and through what mechanisms do highly educated people contribute more to the economy than those with little education? Here we will take as our starting point two exceptional and important contributions that we will use as building blocks for our analysis - one by Nelson and Phelps (1965) and the other by Schultz (1979).

Nelson and Phelps (1965) present a simple growth model where people with higher education contribute to economic growth through two mechanisms. First they are able to pursue regular activities more efficiently than the average worker. Second, and here is the new insight brought by the paper, they are more competent when it comes to exploit new technical opportunities in the economy. To support their second assumption the authors refer to empirical data showing that highly educated farmers introduce new methods before and with better results than the average farmer.

The conclusion from the analysis is that the marginal productivity of the highly educated will reflect the rate of technical change (exogenously given in the model). *In other words the rate of return on investment in higher education will be positively correlated with the rate of technical progress.* In a stationary economy we would expect the rate of return to be low while we would expect it to be high in an economy characterised by rapid technical change. In the light of this model we might expect the impact on economic growth from expanding higher education in Burkina Faso to remain limited as long as its technology base remains stagnant. On the other hand, for a less developed economy that successfully has entered a trajectory of catching-up, the contribution of higher

education would be high. High national rates of unemployment among graduates in certain poor countries (World Bank 2002 quotes graduate unemployment rates of 35% in Sri Lanka and 22% in Nigeria) may be seen as reflecting economies where there is little technical progress. *A general conclusion is that the role of higher education needs to be assessed in the wider context of the national innovation system and that higher education policy needs to be coordinated with a wider set of innovation policies.*

Schultz (1979) follows a similar line of thought but takes the reasoning some steps further. The title - 'The value of the ability to deal with disequilibria' – as well as the reasoning is intriguing, not least since it comes from an economist belonging to the Chicago-tradition within economics (Backhouse 2004). The empirical evidence used as background for the discussion is similar to that used in the Nelson-Phelps paper – it refers to farming in India and more specifically to the fact that while farmers with education were significantly more productive than average in regions where the green revolution took place, this was not the case where methods of farming remained unchanged.

Schultz interprets these and other examples from agriculture and small firms as reflecting that education makes individuals better prepared to 'deal with disequilibria'. When the individual is exposed to change in terms of new technological opportunities he/she will be more or less competent in finding a solution and it is assumed that one major impact of education is to enhance this competence which Schultz refers to as 'entrepreneurial'. He makes the interesting observation that stationary economies are closer to general equilibrium than dynamic ones. Again, we would expect the contribution to economic growth from investment in higher education to be modest in a stationary economy and high in an economy with a high rate of technical and organisational change.

We believe that these two contributions are highly relevant for understanding the role of higher education in the current era and we use them as building blocks for the analysis. But we will extend

the analytical perspective through *a double change of focus* (see box 1). In the two models graduates operate mainly as *equilibrators*. First, we will demonstrate that graduates contribute to economic growth also by being *innovators*. Second, we will demonstrate that in order to understand the real challenges for higher education it is necessary to take into account that *agents learn by doing, using and interacting*. We take into account that graduates when dealing with disequilibria and acting as innovators become more competent in the process of doing so.

This is fundamental since, we will argue, in the current era learning is the most important of all economic activities. We still subscribe to the statement in Lundvall (1992) that 'knowledge is the most important resource and consequently learning the most important process in the economy'. And we see the neglect of 'learning as competence building' as the singular most fundamental weakness of standard economics.

Box 1: A double shift in analytical focus

Learning refers to people and organisations becoming more competent in making decisions but also to people becoming more skilful in what they do. Individuals as well as organisations may learn through problem solving in connection with regular economic activities. Learning results in explicit knowledge about the world as well as in tacit knowledge about how to do things.

Innovation refers to the process of introducing new ideas into the market sphere. Ideas may be new for the whole world but they may also be new locally for a country or for an organisation. Innovation is an interactive process with feedbacks from users and early adopters. At the core of the current innovation process is collective entrepreneurship – several agents interacting and working together to introduce change.

While it is important to understand allocation as efficient use of existing resource it is equally important to understand how new resources appear. While it is important to understand the choices made by economic agents in the context of what we call the learning economy, it is even more important to understand how agents learn and become more competent in everyday economic life. The concept 'innovation system' is used to analyse the adequacy of the institutional set-up of an economy with focus upon innovation and learning rather than allocation and rational choice.

The diagram below illustrates that learning as well as innovation, in principle, may be analysed in analytical frameworks closer to the standard neoclassical economics. It is possible (but not logically satisfactory) to apply the principles of rational choice to the analysis of innovation. It may, for instance, be assumed that 'management of innovation' is aiming at funds getting allocated to alternative R&D-projects according to the private rate of return, taking into account the risk that the projects do not succeed.[4]

	Allocation	Innovation
Rational choice	Standard neoclassical	Management of innovation

Learning	Austrian economics	Innovation systems

Austrian economics (Hayek and Kirzner) share with neoclassical economics focus on allocation of scarce resources. But they present the market as a dynamic learning process where the allocation of scarce commodities is brought closer to the ideal of general equilibrium without ever finding this state.[5]

The graduate as innovator – some results from empirical analysis

In a series of Ph.D.-dissertations organised at Department of Business Studies, Aalborg University, different aspects of the role of higher education in processes of innovation have been analysed (Drejer 1999, Vinding 2002, Dahl 2004, Pedersen 2005, Nielsen 2007). Access to survey data for a big number of firms combined with detailed register data on employee characteristics for the surveyed firms have made it possible to get new insights in this field (Lundvall 2002a; Nielsen 2006).

One interesting result is that the positive effect on the propensity to innovate (here measured as a positive response to the question if the firm has introduced a new product in a three year period) of having of employees with a graduate degree is especially strong in small and medium-sized firms operating in low and medium technology sectors (Lund Vinding 2004). Our interpretation is that in such, often family owned, firms there is a cultural resistance toward hiring graduates creating a gap between what is required and what is actually achieved in terms of personnel. We base this interpretation on the additional result that, after controlling for size, sector and other relevant variables, the independent family-owned firms are significantly less innovative than firms belonging to a Danish or foreign industrial group (Jensen et al 2007).

In a still unpublished Ph.D.-thesis the role of graduates in small firm innovation has been analysed in a rigorous way. The analysis is focused upon small Danish firms originally without academic personnel. It studies the innovation performance in period t+1 distinguishing firms that hire a first graduate in period t from the rest. The analysis demonstrates that – taking into account a series of

relevant control variables – the first-time hiring of a graduate with an engineering background has a significant positive impact on the propensity to introduce a new product (Nielsen 2006).

The analysis goes one step further asking if innovation in period t triggers a demand for skills in period t+1 – this is what we might expect from the analysis of Schultz since an innovation would establish disequilibria within the organisation. Here the result is that there is no significant effect on the hiring of graduates from technical innovation. But the analysis shows that firms that engage in organisational change in period t have a higher propensity to hire graduates with a non-engineering background in period t+1.

Higher education produces both equilibrators and innovators

This is still work in progress based upon Danish data. But potentially it has important direct and indirect implications for higher education.

First, when designing higher education we should take into account that graduates operate both as *innovators* and as *equilibrators*. The results indicate that engineering graduates are more active as innovators while management and social science graduates have a bigger role as equilibrators.

Second, there is a need to consider how well teaching programs prepare students for these respective roles. Below we will argue that traditional teaching modes do not contribute to the competences necessary to fulfil these roles and that there is a lot to gain from changing the methods of teaching in the direction of problem based learning using theory and analytical tools to analyse problems taken from the real world.

Third, we find strong evidence that business organisations where the capability to innovate would benefit from hiring graduates do not hire for institutional reasons. There are barriers at the micro-level operating both on the supply and the demand side that result in a lower innovation capacity for the innovation system as a whole. Owners of small family-dominated companies are reluctant to

hire what they see as alien academics while graduates may be most attracted to environments where they can interact with other graduates Together these mechanisms establish high introduction thresholds for first time hiring of academic personnel.

This last observation may be of special relevance for less developed countries where the *distance from the academic world to the world of industry is big*. The result may be a vicious circle reproducing stagnant technical change. The low demand for graduates in the private reflects cultural barriers that restrict the hiring of graduates. The absence of graduates, in its turn reduces the innovative capability of firms leaving industry in a stagnant mode where the demand for graduates remains modest. We will argue that this has implications for how the university should connect its research and higher education efforts in the local environment.

It also implies that there may be a need for *government initiatives to stimulate demand for 'first graduate hired'* in the firm. In situations with high unemployment among graduates the positive socio-economic net effects of time-limited subsidies may be substantial. The alternative, which seems to be the case in several less developed countries, where the public sector tries to absorb graduate unemployment does not have any positive effect on the innovative capacity of the economy.

Finally, the distinction between graduates as equilibrators and innovators may be useful as illustration of the importance of *diversity* as a basis for understanding the stability and growth of national innovation systems. Peter Allen (1988) presented a case story related to fishery in Canada where he found that the system was sustainable and efficient only because there were two types of fishermen. He called them respectively Cartesians and Stochasts. The Cartesians used rational calculation including all kinds of secondary information based on the experiments made by stochasts who were always on the outlook for new fishery areas.

It would be interesting to follow up on Schultz analysis and analyse different economies as populated by the two kinds of entrepreneurs – innovators (Stochasts) and equilibrators (Cartesians) – and to analyse implications for higher education system. The actual mix in the economy may explain the kind of economic dynamics that characterises a specific innovation system. The successful catching-up witnessed first in Japan and later in Korea and Taiwan had a strong emphasis on engineering skills used to absorb international technology through technological learning. For these countries, as they move closer to the technology frontier, it might be a major challenge to reform higher education so that it gives graduates stronger competence as innovators.

A more indirect lesson is that higher education should aim at a diversified output and that ambitious attempts to standardise the national higher education system should be reined in. The most successful innovation process might typically involve collaboration among engineers and scientists with different approaches to problem solving. In Denmark there are two universities that educate most of civil engineers and they offer two different forms of education. One is more traditional based upon learning through lectures and course work (Denmark's Technical University) while the other makes much more use of problem based learning (Aalborg University). We believe that the resulting diversity in approaches to problem solving among Danish engineers may enrich the innovation system. We see one of the most fundamental strengths of the US higher education system in its diversity spanning from arts colleges and land universities to research universities, both private and public.

Higher education in the learning economy

In this section we take into account that agents involved in innovation and in coping with disequilibria learn and become more competent in the process.

The learning economy as a response to the acceleration in change

In various contexts we have introduced an interpretation of what actually takes place in the economy over the last decades under the heading 'the learning economy' (Lundvall and Johnson 1994). The intention is to mark a distinction from the more generally used term 'the knowledge-based economy'. The learning economy concept signals that the most important trend shift is not the more intensive use of knowledge in the economy but rather that *knowledge becomes obsolete more rapidly than before*; therefore it is imperative that firms engage in organizational learning and that workers constantly attain new competencies.[6]

The speed-up of change can be illustrated by the fact that it is claimed that half of the skills that a computer engineer has obtained during his education will have become obsolete one year after the exam has been passed, while the 'halving period' for other wage earners with higher education is estimated to be eight years (Ministry of Education 1997, p. 56).

Returning to the contribution by Nelson and Phelps we would assume that the relative demand for higher education would increase as the rate of change accelerates. One of the very clear outcomes of OECD's Jobs Study was that in the period after 1985 this was the case in almost all OECD-countries – in all OECD-countries we found that either income differences or employment opportunities became more unequal between those with higher education and those without. A different way to characterise the learning economy is that it is an economy where the demand both for innovators and equilibrators is increased and since those with a higher education are more successful in these roles the relative position of employees with higher education is strengthened.

The transition to a learning economy confronts individuals and organisations with new demands and it has important *implications for higher education.* The most obvious is that the education system needs to give attention to *enhancing the learning capacity* of the students. This does not necessarily conflict with teaching specific and complex bodies of theory or with the use of

specialised tools. But it implies that the way teachers teach and the way students learn becomes crucial.

A second major implication is that higher education institutions need to be ready to support *continuous and life-long learning for academics*. Especially in fast moving fields of knowledge there is a need to give regular and frequent opportunities for experts to renew their professional knowledge.

Finally, rapid change in science and technology and the need to move quickly from invention to innovation presents a strong argument for keeping a reasonably *close connection between* the two basic functions of universities: *education and research*. Teachers who have little or obsolete knowledge about what is going on in current research are not helpful when it comes to give students useful insights in dynamic knowledge fields.

These are implications for fast-changing rich societies with strong emphasis on innovation and learning. What about less developed countries? In the next session we will introduce some fresh European data that show that workplace learning takes place differently in different European countries. Some of these differences reflect different levels of economic development and the analysis of these differences gives us hints on how to link higher education and learning to economic development.

How Europe's economies learn

Lorenz and Valeyre (2006) have developed a highly original and informative EU-wide mapping of the adoption of different types of work organisation with focus on learning opportunities and employees' discretion in organising their work.[7] Cluster analysis is used to identify four different systems of work organisation:

- Discretionary learning (DL).

- Lean.
- Taylorist.
- Traditional forms.

Two of these, the discretionary learning and lean forms, are characterised by high levels of learning and problem solving in work.

The principal difference between the discretionary learning and the lean clusters is the relatively high levels of discretion or autonomy in work exercised by employees grouped in the former. Over 85 percent of the employees grouped in the DL-cluster affirm that they have control over their work pace and work methods whereas only slightly over 50 percent of the employees grouped in the lean cluster affirm this. Task complexity is also higher in the discretionary learning cluster than in the lean cluster.

Referring back, we might say that all those who work in the two learning modes operate as equilibrators – they are regularly confronted with solving problems of reallocating resources as a response to change imposed upon them. But in the discretionary learning cluster we would also find 'innovators' who, confronted with new types of problems, would develop new methods to solve them.

Discretionary learning thus refers to work settings where a lot of responsibility is allocated to the employee who is expected to solve problems on his or her own. Business services are a typical example where many jobs involve a continuous confrontation with new and complex problems. Although some of the tasks take place in a team, teamwork is not seen as imposing narrow constraints on the work. Employees operating in these modes are constantly confronted with 'disequilibria' and as they cope with those they learn and become more competent. But they also experience that some of their earlier insights and skills become obsolete.

Table 1: National Differences in Organisational Models (percent of employees by organisational class)

	Discretionary learning	Lean production learning	Taylorist organisation	Simple organisation
North				
Netherlands	**64,0**	**17,2**	**5,3**	**13,5**
Denmark	**60,0**	**21,9**	**6,8**	**11,3**
Sweden	**52,6**	**18,5**	**7,1**	**21,7**
Finland	**47,8**	**27,6**	**12,5**	**12,1**
Austria	**47,5**	**21,5**	**13,1**	**18,0**
Centre				
Germany	**44,3**	**19,6**	**14,3**	**21,9**
Luxemb.	**42,8**	**25,4**	**11,9**	**20,0**
Belgium	**38,9**	**25,1**	**13,9**	**22,1**
France	**38,0**	**33,3**	**11,1**	**17,7**
West				
United Kingdom	**34,8**	**40,6**	**10,9**	**13,7**
Ireland	**24,0**	**37,8**	**20,7**	**17,6**
South				
Italy	**30,0**	**23,6**	**20,9**	**25,4**
Portugal	**26,1**	**28,1**	**23,0**	**22,8**
Spain	**20,1**	**38,8**	**18,5**	**22,5**
Greece	**18,7**	**25,6**	**28,0**	**27,7**
EU-15	**39,1**	**28,2**	**13,6**	**19,1**

Source : Adapted version based on Lorenz and Valeyre (2006)

Lean production also involves problem solving and learning but here the problems appear to be more narrowly defined and the set of possible solutions less broad. The work is highly constrained and this points to a more structured or bureaucratic style of organisational learning that corresponds rather closely to the characteristics of the Japanese or 'lean production' model.

The other two clusters are characterised by relatively low levels of learning and problem solving. In the traditional cluster, learning and task complexity is the lowest among the four types of work organisation, while at the same time constraints on work rate are relatively low. This class groups traditional forms of work organisation where methods are for the most part informal and non-codified.

Table 1 shows that people working in different national systems of innovation and competence building *have very different access* to workplace learning. The DL forms of work organisation are most widely diffused in the Netherlands, the Nordic countries and to a lesser extent in Germany and Austria, while they are little diffused in Ireland and the southern European nations. The lean model is most in evidence in the UK, Ireland, and Spain and to a lesser extent in France, while it is little developed in the Nordic countries or in Germany, Austria and the Netherlands. The taylorist forms are more present in Portugal, Spain, Greece and Italy, while the traditional forms are similarly more in evidence in these four southern European nations as well as in Germany, Belgium and Luxembourg.[8]

We find that the lower the income level, the bigger the proportion of the workforce that work in either Simple or Taylorist organizations. The richer the country the more workers are employed in learning contexts.[9] One interesting perspective raised by these data is that *economic development may be defined and analysed as a transformation of working life.* Historically we have seen, first, a transformation from simple to taylorist organisation of work as farmers are absorbed by factory work. Later on, an increasing share of the workforce enter into more flexible forms – Lean or Discretionary Learning - and in some current high income the majority of workers work in Discretionary Learning workplaces. One important lesson is that while codified knowledge and advanced science become more important as the economy develops, there is simultaneously an increase in demand for less structured knowledge produced by organisational learning (Jensen et al 2007).

The North-South pattern observed in Europe supports the assumption that industry's capacity to absorb graduates as employees is higher in rich countries than in less developed countries. The pattern also indicates that employees in countries at the technological front learn more than those in poor countries. In general the problem of growing social, international and regional inequality is

fundamental for how higher education systems should be designed in the globalising learning economy. There are several different mechanisms at play and therefore we will treat this set of problems in a separate section below.

Education and training for learning organisations

Since the discretionary learning forms of work organisation depend on the capacity of employees to undertake complex problem-solving tasks in relatively unconstrained or 'organic' work settings, it can be expected that nations with a high frequency of these forms will have made substantial investments in the development of the knowledge and skills of their labour forces. Investments in education and training take various forms and in what follows we compare tertiary or third-level education with the continuing vocational training offered by enterprises both through external and internal courses.

Tertiary education develops both problem-solving skills and formal and transferable technical and scientific skills. A major goal of most EU nations over the last two to three decades has been both to increase the share of their populations with third-level education, and more specifically to increase the number of graduates qualified in science and engineering.

While most of the qualifications acquired through third-level education will be relatively general and hence transferable on the labour market, the qualifications an employee acquires though continuing vocational training will be more firm specific. Some of this training will be designed to renew employees' technical skills and knowledge in order to respond to the firm's requirements in terms of on-going product and process innovation.

Other parts of continuing vocational training, notably the provision of in-house courses, will be more organisationally focused and designed to develop employee competence in the firm-specific routines and operating procedures that are required for daily production activities. This latter kind

of vocational training will be highly complementary to the more informal forms of learning that occur on-the-job, as employees seek solutions to the problems they confront in their daily work.

Figure 3 shows the correlations between the frequency of the DL forms and two of the four measures of human resources for innovation used in Trendchart's innovation benchmarking exercise: the proportion of the population with third-level education and the number of science and engineering graduate since 1993 as a percentage of the population aged 20-29 years in 2000. The results show a positive correlation (R-squared = .26) between the DL forms and the percent of the population with third level education, and no discernible correlation between the DL forms and the measure of the importance of new science and engineering graduates.

Figure 3

Formal education and discretionary learning

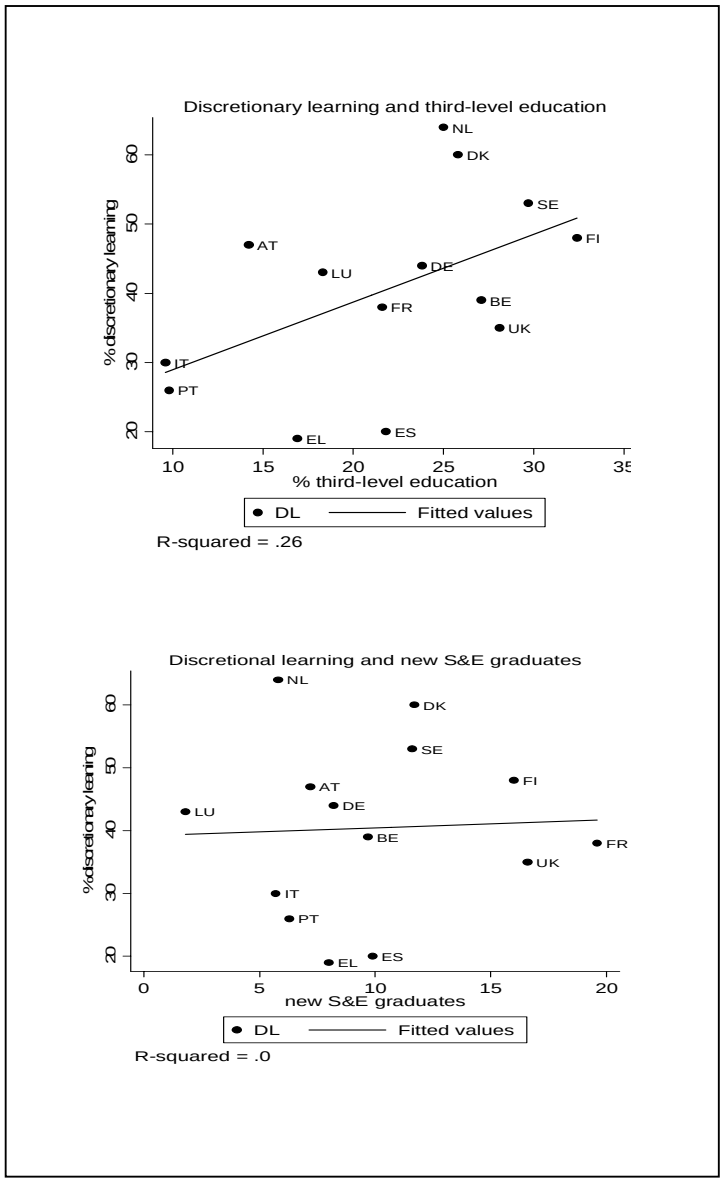

Figure 4 shows that there are fairly strong positive correlations (R-squared = .75 and .52 respectively) between the frequency of the discretionary learning form and two measures of firms' investments in continuing vocational training: the percentage of all firms offering such training and the participants in continuing vocational education as a percent of employees in all enterprises. The

results suggest that these forms of firm-specific training are key complementary resources in the development of the firm's capacity for knowledge exploration and innovation.[10]

Figure 4

Enterprise continuing vocational training and discretionary learning

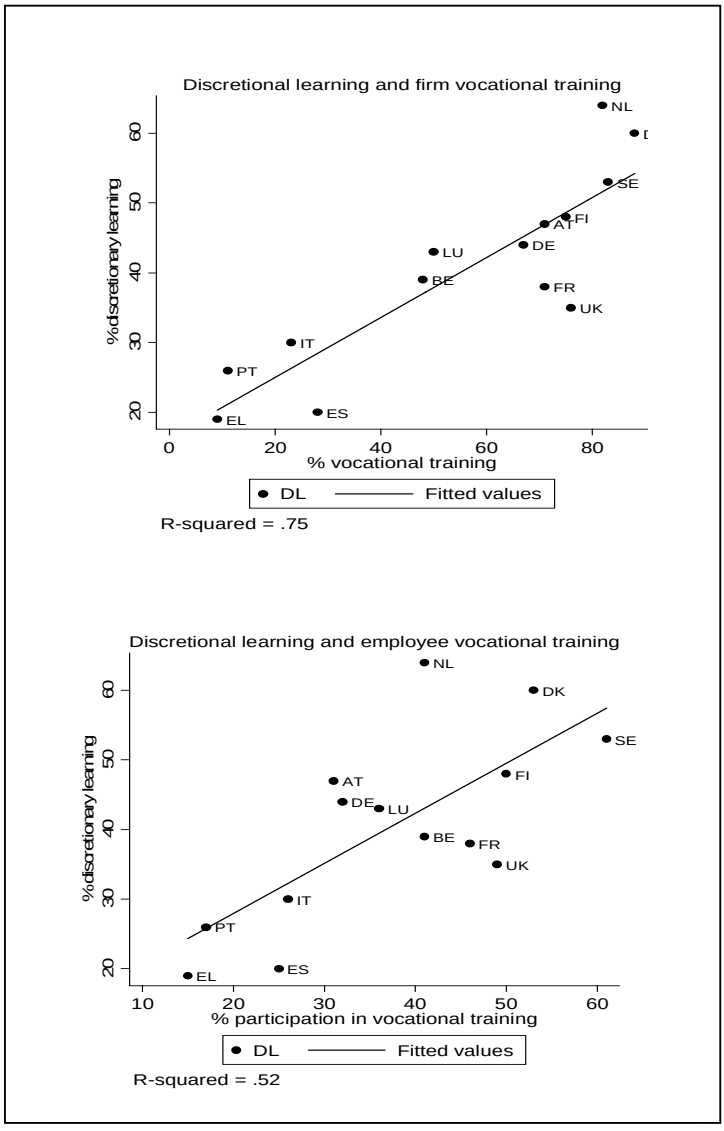

Figure 4 also points to a north/south divide within Europe. The four less technologically developed southern nations are characterised both by low levels of enterprise continuing vocational training

and by low use of discretionary learning, while the more developed northern and central European nations are characterised by relatively high levels of vocational training and by high level use of the discretionary learning forms.

When interpreting the data presented here, it is important to note that much of the continuing vocational training may be directed toward graduates. In Lundvall (2002) we find a strong Matthews's effect in the distribution of training opportunities in Danish firms. The higher echelons with higher education were offered such opportunities much more frequently than were workers with short formal education.

These results do not imply that third-level education contributes little to firms' innovative performance. Rather, the point is that, the bottleneck for constructing learning organisations in a less developed economy would appear to be at the level of firm-specific vocational training and not at the level of formal third-level education. Portugal, Spain, Italy and Greece, all of which have made important strides in increasing the number of science and engineering graduates, stand out for their low levels of investment in continuing vocational training and for ranking the lowest on the discretionary learning scale.

Again, the analysis indicates that investing in higher education will be much less efficient if the economy does not establish the prerequisites for establishing learning dynamics and this includes continuous efforts to upgrade competences at the firm level. In a forthcoming Ph.D. dissertation Keynor Ruiz (2007) on the basis of a series of case studies reveals serious weaknesses of labour market institutions in Costa Rica when it comes to support organisational learning inside firms.

Inequality and learning in economic development

In the next table mapping international differences in the frequency of discretionary learning we make a distinction between what we call 'managers' and 'worker'. Actually the class of managers

include not only top managers but also middle managers and professionals, including technicians, while the worker category includes workers with and without professional training as well as clerks. The table shows that the higher the employees are in the professional hierarchy the higher the probability that they are engaged in discretionary learning. This is true for all the countries.

What is more interesting is that we find a strong indication of different learning modes in different countries. In the most developed economies (with the exception of France and the UK) we find that the inequality in the distribution of learning opportunities is moderate while they are very substantial in the less developed south. For instance, the proportion of the management class engaged in discretionary learning in Portugal is almost as high as in Finland (62% in Finland and 59% in Portugal), but the proportion of workers engaged in discretionary learning is much higher in Finland (38.2% versus 18.2%). Finland is among the highest in income as in innovation activities while we find Portugal at the other extreme on both accounts.

This pattern indicates that a movement toward a learning economy is one where inequality in learning opportunities is reduced. The countries at the top of table are countries where income inequality is low and they are highly successful in adapting to the changes impose upon them by new technologies and new forms of more intense and global competition. So while it might be true that higher education fosters people who are successful as equilibrators and innovators it is when those people interact with a broader segments of the workforce in promoting or coping with change that the innovation system as a whole turns out to be most efficient.

Table 1: National Differences in Organisational Models (percent of employees by organisational class)				
	Discretionary learning*	**Share of managers in discretionary learning**	**Share of workers in discretionary learning**	**Learning Inequality index****
North				
Netherlands	**64,0**	**81.6**	**51.1**	**160.0**
Denmark	**60,0**	**85.0**	**56.2**	**151.2**
Sweden	**52,6**	**76.4**	**38.2**	**200.0**
Finland	**47,8**	**62.0**	**38.5**	**161.0**
Austria	**47,5**	**74.1**	**44.6**	**166.1**
Centre				
Germany	**44,3**	**65.4**	**36.8**	**177.8**
Luxemb.	**42,8**	**70.3**	**33.1**	**212.4**
Belgium	**38,9**	**65.7**	**30.8**	**213.3**
France	**38,0**	**66.5**	**25.4**	**261.8**
West				
UK	**34,8**	**58.9**	**20.1**	**293.0**
Ireland	**24,0**	**46.7**	**16.4**	**284.8**
South				
Italy	**30,0**	**63.7**	**20.8**	**306.8**
Portugal	**26,1**	**59.0**	**18.2**	**324.2**
Spain	**20,1**	**52.4**	**19.1**	**274.3**
Greece	**18,7**	**40.4**	**17.0**	**237.6**
EU-15	**39,1**			

*After correction for job structure and sector composition.

**The index is constructed by dividing the share among 'managers' engaged in discretionary learning with the share of workers engaged in discretionary learning. I fthe share was the same the index woul be =100.

For the design of higher education systems in less developed countries, and also for countries in the south of Europe, these observations raise an issue of how education programs can be designed in such a way that the social distance in working life between 'management' and 'workers' does not become too big. The experience of the Nordic countries, always appearing at the top of global competitiveness assessments together with the US, also demonstrates that public policies reducing

income inequality may actually promote innovation and growth through its positive effect on the participation in learning and change.

Reflections on public policy for higher education

In this section we present some ideas about public policy in relation to higher education based upon our analysis. It is obvious that any attempt to introduce change needs to be based upon broad participation of civil society and not least engage change agents within the academic community. Universities are conservative institutions and in extreme cases it might be considered to build new ones rather than reforming the old ones.

A pessimistic conclusion?

Not so many years ago the World Bank argued against investment in higher education in Africa recommending governments to focus their efforts on primary and secondary education. This recommendation was based on the observed low rates of return on the investments (Samoff and Carrol 2004). Our analysis may be interpreted as leading to equally pessimistic policy implications. We have argued that in poor economies with little technical progress and little economic change the demand for graduates will remain low.

But this is not the conclusion we will draw. As pointed out in more recent World Bank documents investments in higher education should not be assessed exclusively on the basis of the contribution to economic growth (World Bank 2002). And, since there is now agreement that all countries should invest in higher education we are left with a different and more challenges question: *How should higher education be organised so that it contributes to a take-off in terms of innovation and economic growth in a less developed economy?*

But there is a need to combine this with an even more fundamental change of perspective where the focus is moved from promoting supply to creating demand for educated workers. For each single

less developed economy there is a need to develop a strategy aiming at making the national innovation system more active and dynamic. With success, such a strategy would also establish stronger demand for higher education. This perspective requires that *policies for higher education be seen as integral parts of a much broader set of policies aiming at promoting innovation in the economy.*

How to organise universities in a less developed economy?

There are many problems for the policy maker responsible for higher education. Some problems have to do with funding, efficient administration and the quality of teachers and graduates. Here we will focus on one specific set of problems related to *the high degree of separation of the higher education from the rest of society*. We believe that shortening this distance is a key to getting positive results from investment in higher education in less developed economies.

In many developing countries the prevailing 'university models' are the world leading US-universities in the Boston and the San Francisco area, or possibly the universities in Cambridge or Oxford. The idea that each single university should become a world centre of excellence it attractive in the sense that it gives strong emphasis to quality and meritocracy in contrast to corrupt practises and mediocrity. But it is not all for the good. A very bad replica of the star universities may be detrimental to economic development. We believe that there is another US-model that could give more useful inspiration and this is *the land university* with its extension services.

The first of these *regional universities* were established around 1860 with the direct purpose to contribute to regional development and they were supported by regional civil society and by the federal as well state and local authorities. In the 20th century they started to combine research and higher education with an active extension system for distributing useful knowledge to the region. The extension service was not only aimed at the business sector, including farmers, it also aimed at

giving education to housewives and adults in general. We think that universities of this kind may produce graduates that are better equipped to contribute to problem solving and innovation in less developed regions and countries than the standard research university.

It may be combined with establishing one or more *national universities* that consciously try to link up with 'global networks of excellence'. But it is obvious that establishing such elite universities always will result in 'brain drain' – at least as long as the domestic demand for advanced knowledge remains limited. For such universities it is therefore necessary to socialise students in such a way that they graduate with a certain pride of country and university brand to give them some roots in their home country.

The national universities may be linked through collaborative network agreements to the regional universities and job descriptions for professors may include that they should serve at both in order to give regional universities updated knowledge about frontier research. Regional universities should be stimulated to develop advanced research in niches where they reveal strength or in areas where regional demand is strong. Such local forms of excellence should be rewarded on line with the excellence of the national university,

Higher education should contribute to general competences

One of the most important insights from innovation research is that the *innovation process is interactive* (Christensen and Lundvall 2005). Transforming a new idea into a marketable product involves teamwork and inter-organisational interaction with customers and knowledge institutions. In a context of accelerating change, general skills that support learning become increasingly important.

What matters for the performance of a graduate is a combination of professional and specialised knowledge acquired through reading books and following lectures and a set of so called *general*

skills and especially the capacity to communicate, cooperate and interact with others. In a less developed economy such skills involve the ability to interact efficiently in a cultural environment quite different from the academic context.

General competences are sometimes referred to as 'personal' and sometimes as 'workplace skills'. This terminology is problematic since it gives the impression that they are something separate to be added on after the university training has been concluded. One way to make the transition to working life less painful for graduates is for universities to take responsibility for the formation of general skills.

Danish survey data illustrates that there is a close connection between firms engaging in organisational change and learning and the demand for 'social skills'.

Table 4: Changes in task content for employees in the period 1993-95 for firms that have made organisational changes (outside the parentheses), compared with firms that have not made organisational changes (in parentheses).

	More	Less	Unchanged	No answer
a. Independence of work	72,6 (37,1)	4,2 (2,7)	21,2 (56,3)	2,0 (3,8)
b. Professional qualifications	56,4 (36,3)	7,5 (5,3)	33,3 (53,8)	2,8 (4,4)
c. Routine character of tasks	5,6 (8,2)	41,8 (15,5)	45,0 (67,1)	7,7 (9,1)
d. Co-operation with colleagues	59,1 (27,1)	5,8 (4,5)	31,8 (63,3)	3,2 (5,0)
e. Co-operation with management	64,9 (28,6)	5,9 (4,2)	26,1 (62,2)	3,1 (4,9)

Source: Voxted 1999, DISKO-Survey, N=952 (981)

Table 4 shows that there is stronger demand for professional skills in firms establishing new forms of organisation but the gap is much less regarding these than when it comes to general skills. All firms, but especially those that engage in organisational change, require from the experts they hire that they can communicate and collaborate internally and externally.

This implies that the teaching at the universities needs to be adjusted in order to prepare the students for communicating and co-operation with other categories of workers and experts. The way students study and learn at university affects their social skills when they exit as graduates and so does the broader cultural context of the university. In the modern literature on learning this relates to the idea of learning as moving from the periphery to the centre of communities of practise. The idea of education as a process where you fill empty bottles the form of which is determined elsewhere is widely shared but it is inadequate (Guile2003).

University education everywhere has inherited some forms of transmitting knowledge to students such as series of lectures, often in big crowded rooms referring to standard textbooks often based upon the reality of the US or the UK. We would argue that this method of learning is highly inefficient. One problem is the lack of relevance of the substance seen in relation to the concrete context and this problem is of course most dramatic in less developed countries. *Research focused on domestic problems attempting to adopt research methods and tools to the local context may be helpful to develop more relevant teaching material.*

The second problem is that this traditional learning form does not prepare students to use the theory and methods in a real life context and neither does it replicate the kind of learning that is required in a future professional life. In professional life most learning takes place through problem solving, often in a context of collaboration with others with a different background. *Problem-based learning*

and combining theoretical work with periods of practical work is an obvious response to these problems.

We believe that this consideration is especially important in less developed countries where universities tend to select a small group of the population among the elite to become the new elite. Elite education in narrowly defined disciplines may be detrimental to innovation even if it takes place at 'centres of excellence'. Both the socialisation and the selection functions are important for what kind of scientists and engineers that are produced by the national system of higher education. *The way students learn* to become proficient in a specific discipline or profession is thus crucial for how they will function in their future functions.

This also implies that we need a concept and indicators of 'quality' with several dimensions when we evaluate education outcomes. PISA-tests in mathematics, physics and language capabilities need to be combined with tests of 'interactive capabilities'. A high level of the first type of capability is of limited value for innovation if the level for the second type is low. A principal task for higher education is to contribute to *collective entrepreneurship* – i.e. to general skills supporting an interaction with others resulting in innovation.

Students' activities should be at the core of the third mission

When it comes to see university as a source of innovation focus is normally on specific organisations aiming at linking university research to business organisations. Often the focus is on efforts to establish science parks in physical proximity to universities or on engaging universities in patenting their research results.[11] *In contrast, I will argue that universities' most important contribution to innovation remains their formation of graduates with a good problem-solving capacity*.

The strong emphasis policy makers and university administrators put on as separate 'third mission' as compared to the much lower attention they give to reforming 'ordinary education' is highly problematic since it results in a neglect of the substantial gains that could be achieved by modernising the education system. Such educational reforms would have as a central aim to deepen and widen the network relationships between university and industry.[12]

The third mission and the market orientation of universities

In recent years there has been a strong emphasis on reforming universities to take on what has been called 'the third mission'. This has in the literature often been presented as synonymous with the idea that they should become more market-oriented (Etzkowitz and Leydesdorff 2000).

Actually, the stronger market orientation should be kept separate from the idea of strengthening of 'the third mission'. It is important to note that the concept of 'the third mission' goes back to 1914 when the extension service was added to other basic activities at Land Grant Colleges through the Congressional Smith-Lever Act in the US (Graham 1994). The extension services were/are not primarily profit-oriented and the principal aim was not to make money for universities. On the contrary, the establishment and set-up involve strong elements of civic service to serve the local society that supports the local university. A similar tradition of serving local societies and weak segments of the population can be found at universities in many of the Latin American countries (Arocena and Sutz 2005).[13]

Box 2: Three negative consequences of taking the market orientation of the university too far

Closer university-industry interaction may stimulate innovation in the economy. Contract research for firms, informal consulting for firms and many other forms of collaboration may take place without seriously undermining the autonomy of the university, especially if it is built in an atmosphere of mutual understanding and respect and if the collaboration is transparent.

Nonetheless, there are three major potential negative consequences of taking the market orientation of universities too far.

First, installing intellectual property rights on outcomes of academic research cannot avoid having a negative effect on knowledge sharing within and outside the university and it undermines the academic ideal of open access to knowledge.

Second, in the knowledge-based economy, it is critically important for society to have access to an institution that is credible when it comes to critically assess and validate 'what is reasonably reliable knowledge'. There are, as I see it, no serious alternatives to universities when it comes to fulfil this function and making them highly dependent on markets makes them less reliable judges and witnesses.

Third, as universities become simultaneously more international in their scope and more market oriented they will come under the scrutiny of WTO and European competition regulators. The long-term outcome of this might be that, since fundamental research and normal higher education cannot be clearly separated from their commercialised activities, public funding for these core activities may become classified as illegal subsidies of business activities. This would certainly undermine the very foundation of the knowledge-based society.

In Lundvall (2002b) I have argued that to balance the need to get closer to the business sector with the need for a certain relative autonomy a diversification of the university activities with protected realms for 'slow and deep research' may be the only solution to the dilemmas facing universities.

To argue that reluctance to transform universities into profit-oriented business organisations is to support an 'ivory tower' model is thus highly misleading. Actually, to engage universities in protecting and selling knowledge in the form of patents may be seen as building equally inaccessible 'business towers'.[14]

The third mission and higher education

To isolate students on campus for three to five years and exclusively expose them to university teaching for this period is not the best way to train students. Laboratory work and construed case material does not establish sufficient links between theory and practise. In most disciplines and professions students can learn from analysing problems outside university. Periods of fieldwork or practical work periods related to the object of study are useful in preparing students for a future career. Educational programs should be organised in such a way that students can contribute to the

third mission of the university and at the same time profit from it in terms of learning. Longer educations may be split up into parts with periods of practical activity in between.

It is often neglected that the success of 'third mission' programs will reflect not only the supply side but also the demand side. For instance, firms without personnel with a higher education will not be prepared to/capable to interact with universities. Educating graduates in such a way that they find employment in industry is therefore a key also to strengthen university-industry collaboration. Below we illustrate this by combining labour market data with survey data on industry-university collaboration.

Table 2: Share of firms that have strengthened their co-operation with knowledge institutions related to size of the business and amount of employees with higher education (HE) - Percentage that have cooperated in connection with product development.

	49 employees or less			More than 49 employees		
	HE>2	HE<2	All	HE>2	HE<2	All
Increase in co-operation	19	9	11	35	24	26
No increase in co-operation	81	91	89	65	76	74
Total	100	100	100	100	100	100
N (%)	156 (16%)	827 (84%)	983 (100%)	142 (24%)	460 (76%)	602 (100%)

*Source: Nielsen 1*999

Table 2 shows that firms with employees with more than two employees with a higher education are more prone to collaborate with universities and other knowledge institutions than firms with less.

For small firms the probability of intensifying the co-operation with a science institution is twice as high when the business has more than two employees with higher education. One important way to increase the interest in firms to hire academic personnel and on this basis to collaborate with universities is to establish some kind of exchange already during the study period. As mentioned above, time limited marginal employment subsidies to private firms hiring graduates is a possible policy response.

Promoting Excellence when knowledge attracts knowledge?

One of the important consequences of the move toward a globalising learning economy is that inequality becomes a major problem at all levels. The globalising learning economy concentrates both knowledge and incomes at all levels as long as market mechanisms are given free play. This constitutes an inherent contradiction in the globalising learning economy since learning seems to be especially successful in contexts with small gaps in income and social status – cf. the data on discretionary learning in the Nordic countries. The new distribution problem calls for 'a new new deal' where focus is upon redistributing 'learning opportunities' and 'learning capabilities'. It is therefore a major task for international organisations and national governments to find ways to stimulate such redistribution.

One dimension of the growing inequality is the geographical concentration of wealth and knowledge. We have seen that the more knowledge is advanced the more new knowledge is created in a region through processes of learning and innovation. Within countries we also see similar patterns of growing regional gaps in knowledge and income.

Knowledge used in the economy always has tacit elements that make it difficult to move it from one site to another. Since it is more expensive to produce new knowledge than it is to use it on a wider scale, certain locations will become very active in terms of innovation. It is easier to develop

complex new technology at a site located close to advanced knowledge institutions, sophisticated suppliers and customers than at a site without a strong knowledge infrastructure.

In the learning economy the increasing mobility of people reinforces global as well as regional inequality. For individuals eager to advance in the learning economy it is rational to move to places where a lot of learning taking place. There might be other specific attractors for 'the creative class' (such as a high frequency of rock concerts or bars for homosexuals as found in the work by Richard Florida) but the most basic attractor is that there are already other creative people in the locality and there are ample learning opportunities in the area.

Similar mechanisms are at work in the competition between higher education organisations. They are reinforced by public rankings making students and professors eager to join certain highly prestigious universities. Allocation mechanisms giving extra resources to those universities that publish most will contribute to the increase in the gap between the elite universities and the rest.

In public policy there is certain ambivalence in relation to these phenomena. On the one hand most national ministries of education or science aim at establishing one or more 'world class universities'. But on the other hand it is obvious that concentrating all education and research at very few universities would result in an extremely uneven regional distribution of knowledge and economic development.

Especially for less developed countries it is highly problematic to allocate resources mainly to the most established universities with the most highly developed international connections. Many of these resources risk becoming part of the global drain in the direction of rich countries and multinational companies (Hoebink and Van der Zanden 2004).

This is why one further reason why we propose that regionally anchored universities should be given a fair share of resources for research and education. Actually such universities may also be

more flexible when it comes to experiment with new forms such as problem-based learning methods and interdisciplinary research.

Conclusions

I am painfully aware of the fact that there are many difficult policy issues related to higher education that have not been given sufficient attention in this paper. Rather than listing those and analyse each separately I have tried to deepen our understanding of some general mechanisms that link higher education to economic development and tried as well to draw some policy implications on this basis.

To get a fresh perspective, we have focused more on learning and innovation and less on rational choice and allocation of existing resources. We find that the major problem for higher education in many countries is a lack of domestic demand that reflects an incomplete and stagnating national innovation system. Therefore we have focused on reforms of the higher education system that might contribute to a building of a more complete and dynamic innovation system. Most of the reforms have aimed at shortening the distance between higher education and society to make the transfer from university to work less painful and at the same time to build new and more solid bridges between universities and industry.

But higher education is only one part of the national innovation system. In order to break out of vicious circles there is a need for a comprehensive national strategy rooted in a strong common engagement to change. Such a strategy needs to be based upon a solid analysis of the national innovation system. Such a strategy needs to give much attention to human resources in general, not only higher education, but also including for instance labour market institutions. It also needs to include an industrial policy aiming at developing economic activities matching domestic competences but with positive learning curves. Studying innovation systems in Latin America,

Africa and Asia we have found little evidence, that market forces spontaneously will establish the necessary prerequisites for catching-up (Gammeltoft, Lundvall and Muchie 2003; Lundvall, Interakummerd and Lauridsen 2006). In this respect, developing countries have more to learn from Friedrich List and 'The Other Canon' than from Adam Smith (Reinert 1999).

Actually, the poorest countries in Africa and elsewhere might not be able to break out of their vicious circles by any kind of intelligent technocratic effort – not even with substantial international aid. In these countries it might be necessary with social mobilisation from below that might result in a collective effort to engage in far-reaching social and political change. The history of my home country Denmark demonstrates that this can take place in a quite peaceful way. The radical transformation of Danish agriculture in the second half of the 19th century laid the foundation of a growing and successful economy (2005 Denmark was ranked as the world's most competitive economy by the UK-magazine the Economist). A fundamental prerequisite for this transformation was the ideological mobilisation of the small farmers, the establishment of folk high schools that gave the farmers self-confidence and knowledge and the cooperative movement. Spiritual leadership is important: Without the active role played by the popular and charismatic priest Grundtvig the process might not have taken place at all.

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Appendix: What can be learnt from the Globelics experience?

By Bengt-Åke Lundvall

Globelics (see www.globelics.org) held its first informal meeting outside Aalborg 2002. The concept was developed over the three previous years in discussions I had with colleagues from the South (Cassiolato, Gu and Muchie) and the North (Soete, Johnson, Freeman and Nelson). The first Annual Conference was held in Rio 2003. After followed annual conferences in respectively Beijing (2004), Pretoria (2005) and Trivandrum (2006). Next year's conference will take place in Saratov, Russia.

Globelics is a global research community combining scholars working on innovation studies with scholars working on development studies. It has been characterised as a network for 'researchers without borders' (Luc Soete). All the Globelics annual conferences have taken place in developing countries and the finance has been raised within the hosting country. Scholars from the North contribute to keep costs down by raising their own travel funds and they also try to raise some support for young scholars travelling south-south.

Besides the annual conferences, regional and national networks have been established in Asia, Latin America and China (see www.cicalics.org). Each year 40 Ph.D.-students, coming equally from Asia, Africa, Latin America and Europe, are invited to Globelics Academy in Lisbon where world-leading scholars in innovation studies for 10 days period give lectures and methodological advice for their thesis work. A similar Cicalics Academy takes place in China every year with a majority of Chinese students and of international lecturers. New initiatives in Africa and India may soon result in similar activities in these areas.

The purpose of globelics is to counterbalance the increasingly uneven global access to research networks. It gives scholars in less developed countries access to the most recent research and it opens up channels for publication of their work. It also makes it possible to share experiences among scholars from different parts of the developing world, by-passing the metro poles in the North. Several major research projects with global scope use globelics as host – the Catch-Up project coordinated by Richard Nelson, The Brics-project co-ordinated by Jose Cassiolato and the Unidev project co-ordinated by Claes Brundenius.

Globelics has a scientific board with distinguished scholars such as Christopher Freeman and Richard Nelson and with leading scholars from the South. But basically Globelics is a self-organising global network. It draws its energy mainly from the fact that scholars from the North and the South find it highly rewarding to work together and learn from each other in a seriously committed but friendly atmosphere.

One major long term positive effect is that young scholars from all parts of the world, sometimes working in isolation and under difficult conditions, get inspiration and support in their effort to do good research on innovation. There is already a lively 'globelics community' of young scholars who correspond regularly on both a scientific and a social basis.

It is difficult to say if the globelics experiment can be replicated in other fields of knowledge. The innovation research community has always had a strong social dimension that was brought into it by the leading scholars in the field Christopher Freeman, Keith Pavitt and Richard Nelson. Without this social capital the experiment might have failed. If it could be replicated it would certainly be a highly efficient way of contributing to capacity building in the South. It is low-cost and highly productive in terms of publications and research training. And it is certainly more enjoyable than most other research endeavours.