ENGINEERING FOR THE ECONOMY OF THE 21st CENTURY

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SUMMARY

This paper discusses the importance of technological innovation for developing regions, which implies the introduction of improved products and existing processes, which in turn involve a series of scientific, technological, organizational, financial and commercial actions. Thus, it emphasizes the importance of the ability of engineering professionals to innovate and adapt to the constant transformations that are presently taking place, since this capacity can determine the productive development of a region or country. It also proposes that economic development is not only economic growth; therefore, an aspect to consider is the training of professionals, whose preparation should be the result of academic strategies that allow engineering schools to take advantage of location, experience and other specific conditions, for the development of specialties of global reach. Lastly, it is suggested that the low priority given to science and the modest technological results achieved in Chile and similar development countries are not correlated with the efforts made to improve higher education. Thus, we conclude that schools of engineering must be an efficient interface between the regional reality in which we are immersed and the need for scientific and technological development.

Introduction

Innovation is initially a philosophical and social construction process, and it should integrate and cover different fields, such as universities, businesses, Governments, associations, institutes and research centers. The concept of technological innovation has evolved throughout history and it has been present since the era of the classical economists; gaining greater strength nowadays. The reason for the permanence of innovation in time is that technological innovation is considered essential to the socio-economic development of countries.

The concept of innovation has evolved over time, in relation to the understanding of what we want to innovate and the agents that are part of this system. Thus, it transcends the purely technological vision and it can be understood as the use of scientific knowledge to generate new ways to develop, produce, market and distribute products and services.

In this work, we will understand that technological innovation includes the introduction of improvements in existing processes and products, and it involves a series of scientific, technological, organizational, financial and commercial activities (OECD, 2007). Thus, we will include in our analysis aspects related to the origin of technologies and their positive and negative edges when they are introduced in societies that do not produce new knowledge and which encounter difficulties for their insertion. Within this context, the ability of engineering professionals to innovate and adapt to the constant transformations that innovation requires, can determine the productive development of a region or country, so we will consider aspects related to the training of engineers.

Development is possible, even starting at very low levels, provided that favorable decisions for its expansion are made. Intellectual and cultural (educational) investment is essential for development. Thus, we understand development as a process of transformation of society, characterized by an expansion of its production capacity, which implies higher productivity and income per person; variation that produces changes in the structure of social classes and groups, which in turn promote transformations in political structures and power (Villarroel, 1999).

There are multiple approaches to characterize development and some are deeply opposed. Fundamentally, there is a set of ‘utilitarian’ approaches to development, and others that are ‘egalitarian’. The formulation of public policies will depend on the criteria to be adopted and in this sense the adoption of one or another approach will respond to controversial value judgments. As far as we are concerned, the policy for the training of engineers and scientists generally tends to be based on egalitarian approaches. By way of example, when it comes to capabilities (Sen, 1999), education is fundamental for the development of individual and collective capacities, from an egalitarian perspective.

A more general approach is based on the concept of social capital that Putnam (1993) defined as the components of the social organization, which include networks, partnerships and trust norms, which create externalities that allow action and cooperation to create mutual benefit. Within this context, regardless of the political orientation or community values, a region will be more productive to the extent of its social capital. The key to this concept are externalities, because they will manifest themselves in the amount of information that is shared by people and business, which will contribute to make the most of opportunities, mutual aid and

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INGENIERÍA PARA LA ECONOMÍA DEL SIGLO XXI

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RESUMEN

En este trabajo se analiza la importancia de la innovación tecnológica en las regiones en desarrollo. Esto implica la introducción de mejores productos y procesos, que en su conjunto involucran una serie de acciones científicas, tecnológicas, organizativas, financieras y comerciales. Por lo tanto, se hace hincapié en la importancia de la capacidad de los profesionales de la ingeniería en innovación y en adaptarse a las constantes transformaciones que se están produciendo en la actualidad, ya que esta capacidad puede determinar el desarrollo productivo de una región o país. También plantea que el desarrollo económico no es solo el crecimiento económico y, por lo tanto, un aspecto a tener en cuenta es la formación de profesionales cuya preparación debe ser el resultado de estrategias académicas que permitan a las escuelas de ingeniería tomar ventaja de la ubicación geográfica, la experiencia y otras condiciones específicas, tal que permitan el desarrollo de especialidades de impacto regional. Por último, se manifiesta que la baja prioridad dada a la ciencia y que los modestos resultados tecnológicos conseguidos en Chile y en países de similar desarrollo, no están correlacionados con los esfuerzos realizados para mejorar la educación superior. Por lo tanto, llegamos a la conclusión de que las escuelas de ingeniería deben ser una interfaz eficaz entre la realidad regional en la que estamos inmersos y las necesidades de desarrollo científico y tecnológico.

ENGENHARIA PARA A ECONOMIA DO SÉCULO XXI

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RESUMO

Neste trabalho se analisa a importância da inovação tecnológica nas regiões em desenvolvimento. Isto implica a introdução de melhores produtos e processos, que em seu conjunto envolvem uma série de ações científicas, tecnológicas, organizativas, financeiras e comerciais. Portanto, é destacada a importância da capacidade dos profissionais da engenharia em inovação e em adaptar-se às constantes transformações que estão acontecendo hoje em dia, uma vez que esta capacidade pode determinar o desenvolvimento produtivo de uma região ou país. Também sugere que o desenvolvimento econômico não se refere apenas ao crescimento econômico e, portanto, um aspecto a ser levado em consideração é a formação de profissionais cuja preparação deve ser o resultado de estratégias acadêmicas que permitam às escolas de engenharia tomar vantagem da localização geográfica, a experiência e outras condições específicas, de forma a permitir o desenvolvimento de especialidades de impacto regional. Por último, se manifesta que a pouca prioridade dada à ciência e os modestos resultados tecnológicos alcançados no Chile e em países de similar desenvolvimento, não estão correlacionados com os esforços realizados para melhorar a educação superior. Portanto, chegamos à conclusão de que as escolas de engenharia devem ser uma interface eficaz entre a realidade regional, na que estamos imersos, e as necessidades de desenvolvimento científico e tecnológico.

economic security. Thus, social capital will affect expectations and therefore individual and collective behaviors.

The concept of social capital is elusive and requires more precision to make it operational. The literature on social capital usually emphasizes the existence of a set of networks as an indicator of social capital. Also social capital has been associated with an economic and financial institutional structure. Within this context social capital would have direct effects on the economy through the reduction of transaction costs and the increase in the efficiency of resource allocation. It would also have indirect effect on the value of education (and other forms of investment in human capital) and in the access to resources such as credit.

Several studies (Smulders and Beugelsdijk, 2004; Chou, 2006; Growiec and Growiec, 2012; Annen, 2013; Ponzetto and Troiano, 2014; Agenor and Dinh, 2015) show that investment in social capital enhances and improves the results of other types of investment. Thus, investment in human capital and infrastructure becomes more profitable when accompanied by increases of social capital.

Technology Transfer

Another important factor that establishes links between concepts and operations is transference. No innovative creation would be possible without the mediation of transference processes. Transference constitutes a true bridge between discoveries and ideas seemingly unconnected and distant both in space and in time. Thus, every educational process is based on transference, its mechanisms, principles and laws. So, as far as we know how transferring is done, what conditions and what operations of thought are participating in the transfer process, we can find ways to speed it up and improve it. Under these conditions we should ask ourselves, what are the conditions for an adequate technology transfer. Technology transfer is usually a mechanism of propagation of capabilities between countries, regions and other human groups, with different levels of development. The transfer can occur regarding products and processes of production, as well as knowledge. Within this perspective, the significant differences in *per capita* income observed in different countries cannot be explained solely by the accumulation of physical and human capital, as this perspective is consistent with 'endogenous growth' theories. The concept of endogenous economic development basically rests on the externalities of investment in human capital (Lucas, 1988) or on knowledge spillovers arising from concentrations of human capital (Romer, 1990).

Endogenous growth theories rest on the hypothesis that investment in human capital allows economic growth to hold indefinitely. This would happen because, unlike physical capital investment, human capital would not have diminishing returns. So, an increase in production would occur through complex activities, which would produce flows of knowledge transfer, through more stimulating environments, which would increase productivity through the accumulation of knowledge and the development of ideas. Thus, many economists have seen technological change as the most important force for strengthening the process of economic growth. Within this perspective, the differences in technological development represent one of the most meaningful explanations for income disparity; the production of technology thus being a determining factor in the distribution of per capita income in the world.

Developing countries largely base their production on research and innovation emanating from developed countries, because technologies can now migrate more easily due to the reduction of transportation costs and the advancement of information technology (Piva, 2003). The fact that many technologies used by underdeveloped countries are imported from developed countries and that this process is probably inappropriate for their economies, could help explain the differences in productivity between these countries, since the economic structures and their needs are different.

The difficulty in the use of different technologies in countries of different capacities was first discussed by Atkinson and Stiglitz (1969), who proposed the idea of 'appropriate technologies', based on the concept that the improvement of technologies does not necessarily increase productivity. The application of new technologies does not deliver the same results in different countries. When adopting a transferred technology, positive consequences and spillovers, technological updating and complementary growth of firms receiving the transfer, should be considered. The negative impact of transferences, such as the termination of production of native technologies, the displacement of workers and the effect of competition with local industries, should also be considered.

Within this context our engineering schools are faced with a challenge of ample proportions. On the one hand they should try to meet international standards and on the other hand, they should seek to establish a relationship between them and the prevailing needs of their countries, in terms of production of science and technology. Here arises the difficulty for defining appropriate guidelines for action, since using foreign high-tech does not necessarily lead to benefits for the development of the transfer host country.

The situation described before represents a complex problem, as the universities located in developed countries are entities that drive scientific and technological progress, which is consistent with the structure of a society that is characterized by the presence of large industrial complexes. As a result, university and industry successfully complement each other in their activities.

The situation in Latin American countries (peripherals from the production point of view) represents a completely different scenario, because these countries do not possess the adequate technological potential that would allow them to generate development, as there is a poor correlation between scientific production and production technologies.

In Latin America, scientific productivity is well below that of developed countries. With more than 100,000 articles published since 1996, Chile shows the highest per capita productivity in Latin America. However, if comparison is made with the rest of the world, Chile is in 44th place, below countries such as Ireland or Greece (Scimago, 2017).

Likewise, Latin America does not stand out because of its ability to appropriate knowledge produced through patents or business research, nor because of its ability to export manufactured or high technology products in significant volumes (Worldbank, 2017).

Finally, possibly because of the above, the Latin American countries invest a smaller proportion of their GDP in research and development as shown in Figure 1.

In fact, the disconnection between science and technology is not only a phenomenon taking place in third world countries. The USA and Europe had a similar scenario back in the 80's. The best example of how this problem can be addressed is illustrated by the Bayh-Dole Act (1980) that was passed when the North American industry was losing ground within the US markets. Indeed, since the end of the 70s, Japanese companies had managed to penetrate the American market with industrial products of all kinds and, paradoxically, most of the executives and technicians from entering Japanese companies had been trained in universities in the USA. On the other hand, the U.S. Federal Government had accumulated thousands of patents derived from research projects funded with federal resources, which were not commercially applied. An interesting aspect of the Bayh-Dole Act was the authorization granted to research institutions for selling industrial patents originated in projects financed with federal funds. An American policy that resulted in an increase of 2.5 times the number of patents originated in universities in a 10-year period and was called the 'New Economy', a model that was soon followed by the European Union (EU), with similar results.

Paradoxically, when we look at Chilean (the Latin America leader) policies for developing science and technology, the possibility of implementing a Bay-Dole bill has never been raised.

The National Commission of Science and Technology (CONICYT), through its support to science only requires acknowledgment of financial contribution in the development of the products obtained from the projects it funds (patents included). A second problem with scientific work in Chile (which has no explanation) is the scant scientific collaboration among researchers from different universities. In science, competition is irrelevant and indeed, the most dynamic countries in scientific production tend to form research networks that allow the circulation of ideas and a shared use of resources, an attitude that is the antithesis of what happens in Chile. A recent report by the OECD shows the isolation of the Chilean and the Latina American OECDs members in scientific production, against the intense collaborative work existing in countries of greater scientific development (OECD, 2014).

It should be highlighted that the low priority assigned to science and the modest tech-

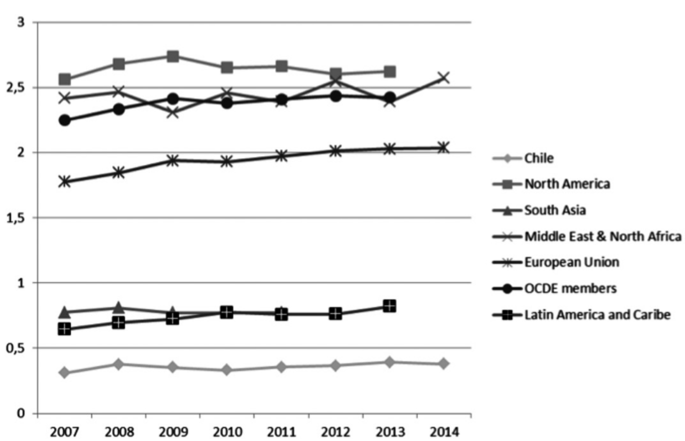

Figure 1. Research and development expenditure (% of GDP). Source: World Bank Databank (http://databank.worldbank.org; Jan/2017).

nological results are not correlated with the efforts to improve higher education in the case of Chile. Indeed, the allocation of resources to tertiary education as a proportion of GDP is the largest in the OECD (2015). In addition, private spending in higher education in Chile is also the largest among OECD countries.

If endogenous growth theories are correct, education must be strongly supported, as the social benefits obtained from it are greater than individual gains. In addition, engineering schools seem to be directly involved in local development through scientific production and elaboration of technology. Within this context, it should be noted that the perspective of growth imposes nothing less than a change in the mission of Chilean universities. Indeed, prior to these new theories, professional training was perceived as a private investment in human capital. From that point of view, the mission of universities was to train competent professionals for specific and well-defined functions and, by the same token, the standard to measure the academic quality of the programs was the salary their graduates obtained in the labor market. Opposite to the above, endogenous growth theories lead us to conclude that human capital formation benefits far outweigh those received by individuals who receive such training. As noted, the social benefits of subsidized academic programs are greater than the benefits obtained by those who invest in their professional education.

From the endogenous growth theoretical concept, universities assimilate new functions and institutional responsibilities. Indeed, endogenous growth theories and its sustainability in a territorial economic unit (town or region) will depend on the human capital located in that area. The interactions between the repositories of human capital (the academy primarily) and economic agents (companies) will generate the necessary economic climate for the innovation and entrepreneurship that will generate wealth. Thus, the training of professionals is necessary, mainly for the growth of countries, regions and economic zones.

In fact, an endogenous growth model, where overflow is considered as an external effect, implies that that optimal investment policy should subsidize education to the extent that this subside implies an investment in human capital. However, there are many aspects that must be clarified. This is necessary because the sequence, causal order and link between human capital and economic growth, is even less clear.

The Spatial Limits of Externalities

At this point, it should be understood that investment in human capital externalities refer to an 'economic space' and that this is not necessarily associated with a geographical delimitation or political administration. In a seminal article on the topic, Lucas (1988) warns about this theoretical ambiguity. The construction of the endogenous model involves countries, but Lucas warns us that this arbitrary theoretical ambiguity, which comes from multiple forms of human interaction, takes place in the development process.

National cases (countries)-based tests yield mixed results. Some empirical evidence shows that the externalities associated with human capital are minor or simply non-existent when the levels of aggregation are countries. However, the statistical tests associated with cities and towns are more consistent. In several studies (Jaffe *et al*., 1993; O'hUallachain, 1999; Acs *et al*., 2002; Carlino *et al*., 2005; Bettencourt *et al*., 2007), a significant relationship between size of the cities and industrial patents production was found. Patents are considered in these studies as an indicator of innovative activity. Also, the evidence shown in these studies is consistent with the idea of a connection between the size of cities and the number of industrial patents that are produced. Moreover, the increment in patent production is non-linear and it exceeds the population difference of the cities studied.

The significant aspect of the endogenous model for this study is that technological innovation is difficult to achieve in small urban centers. Recently, several papers based on Unit Territorial Statistics (NUTS, from *Nomenclature des Unités Territoriales Statistiques*) as defined by the EU in 2003, deal with this aspect. In such studies results are consistent with endogenous development theories. In these works, the discussion about the capacity of absorption of knowledge shown in some regions and its influence on innovation and productivity of human capital is crucial.

Cohen and Levinthal (1990) have defined the capacity of absorption of new knowledge as the ability of a company to recognize the value of assimilating new information that is external to it, so as to use it with commercial purposes. This definition has been applied in studies at regional levels by several researchers (Cantwell and Lammarino, 2003; Doloreux and Parto, 2005; Roper and Love, 2006; Von Tunzelmann, 2009; Mukherji *et al*., 2013; Miguélez and Moreno, 2015). The concept of absorptive capacity of knowledge has been modeled using the link between research and development (R&D) spending and the mobility of the inventors, as well as the existence of innovation networks and innovative companies. The empirical results show that this ability of absorption of new knowledge is relevant to explain the innovation in regional units.

Other works at this level of aggregation (NUTS) show that the distance and contiguity of regions that are rich and highly developed, play a significant and important role in labor productivity and regional growth (Lopez-Bazo *et al*., 1999; Badinger *et al*., 2004; Vaya *et al*., 2004; Le Gallo and Dall'erba, 2006; Meliciani and Peracchi 2006; Fiaschi and Lavezzi, 2007; Battisti and Di Vaio, 2008; Ramajo *et al*., 2008; Benos *et al*., 2015).

A work based on NUTS estimates the impact of business schools in this territorial aggregation in the UK (Guerrero *et al*., 2015). These authors used university actions in education, research and business, and found that they contribute to the economic growth of the 'NUTS' that host them. The impact of research and technology transfer and its contribution to the economic growth of NUTS is also remarkable.

A previous work on this matter found evidence that is consistent with what was stated before (Sterlacchini, 2008). This study is related to the growth of regional economies with R&D expenditure and the proportion of people in higher education at almost 200 'NUTS' of the EU. In aggregate terms both variables (expenditure on R&D and tertiary education) cannot be accounted for regional development. However considering them altogether, they produce statistically significant and satisfactory results.

On this respect, evidence reveals that spending on R&D, by itself alone fails to 'produce' development, unless the population is able to assimilate and transform the new knowledge into economic development. However, the impact of spending and development as a simultaneous phenomenon is heterogeneous in European regions. In particular it is observed that the link is much stronger in the countries of Northern Europe (Belgium, Finland, Germany, and Netherlands) than in the South (Austria, France, Spain, Italy, Greece, and Portugal).

This difference can be explained in several ways. Recent studies (Acs *et al*., 2004) provide important evidence indicating that the missing link in the equation is the minimal entrepreneurship volume in less developed regions. In synthesis, geographic location is relevant in the analysis of growth and economic development. This scope must be well defined, the reason why the creation of the NUTS in the EU is useful as a frame of reference of public policies. Based on this evidence we can say that it is clear that the size and complexity of the geographical frame of reference (city, country, NUTS, etc.) is important when it comes to explaining economic vitality.

In this sense, the challenge of a college and schools of engineering in small and distant regions is complex. A successful engineering program must overcome limitations on the size and the complexity of the economic environment. Therefore, for an efficient university contribution to the development of isolated or remote regions, we need universities to negotiate entrepreneurial agreements with companies for R&D and set up business incubators and other support programs.

Complementarity, Substitution and Priority of Investment in Human Capital

From the public policies perspective, investment in human capital must compete for the allocation of resources among alternative investments. In addition, the effectiveness of the investment alternatives not only should be measured in terms of performance, but also in terms of the sustainability of economic growth. Both criteria should produce orders of priority in the allocation of resources for investment. Within this context, it is important to consider that investment in human capital tends to be complementary to other forms of capital (public works, legal and institutional assets, R&D or others). Also, education levels follow a sequence that makes them strongly complementary.

Endogenous growth models always consider several factors of production that are linked through a production function, where some of the factors are substitutes. However, when adding externalities in the productive function, the relationship between factors becomes unpredictable. Also, in this theory (endogenous growth), the source of unlimited growth are externalities, which are not subject to diminishing returns.

The development of verifiable functional specification models has empirically shown in the last 20 years that this is not a simple task. Small variations in the models produce very different conclusions. For example, in some models R&D should not be financed, but the acquisition of technologically advanced products should be funded. By the same token, some recent evidence suggests the need (or not) for financing higher education in engineering and the conditions in which this should be done or not. The allocation of resources to R&D is a recurrent recommendation for increasing productivity and economic growth.

Higher financing of R&D has direct effects on innovation and new business. It also has indirect effects through the overflow of knowledge and learning by practice. The discussion is not about whether R&D should be subsidized but, rather, how to do it (Romer, 2000). A recent study compares the efficiency of spending on the training of scientists and engineers (S&E) through a long-term model, which is backed by empirical evidence (Grossmann, 2007). The results are favorable to investment in S&E because R&D subsidies cannot ensure growth of productivity or an increase in welfare. R&D subsidies raise the profitability of studies that are useful for those who decide to study science and engineering.

If the educational system does not increase spending (because it is financing R&D), it can cause congestion in the labor market and thus a decrease in the wages of skilled workers. In addition, the effect of congestion is the dispersion of wages among highly qualified people, and among scientists and engineers directly involved in R&D activities. The cause of this is the increase in the profitability of R&D (due to subsidies given to the sector).

So the efforts to increase innovation and productivity can end up concentrating its benefits on a highly productive small group dependent on the extension of subsidies. On the other hand, subsidies to the formation of S&E, do not necessarily affect the distribution of income, but ensure permanent growth of productivity.

A set of propositions consistent with the Grossman model emerges from the so-called 'Sapir report'. This report intends to increase resources for the training of graduate students. (Sapir *et al*., 2004). A Community policy should target talented students to train them with a high level of professional excellence. Sapir *et al*. also suggest that it is necessary to support a wide variety of academic disciplines (beyond science and engineering) and, especially care for the excellence of graduate programs. According to them, the pertinence of public expenditure stands on the effectiveness of education in different fields and the linking of this with the dynamic sectors in R&D. The Sapir report even proposes to reformulate the combination of subsidies to R&D and S&E, also suggests reducing the subsidy to R&D and financing equipment only. The Sapir report results are fully consistent with Grossman (2007) although they are developed from completely different statistical and methodological perspective.

Educational Level and Growth

One aspect that cannot be ignored is that professional training is one of the last links of a learning process and as such, it competes for public resources with the other educational instances. In fact, the most interested in improving general education are the institutions of higher education. This problem is present in developing countries, where funding for general (primary and secondary) and higher education is a field where it is often difficult to make decisions. In middle income countries like Chile, the existence of vulnerable groups that are excluded from development is unacceptable; but financial constraints do not allow investing in all that is deemed necessary.

Within this context, many middle income countries are caught in what is known as 'the middle income trap', which is characterized by a growth rate that is slower than in earlier stages. This phenomenon has been described by Eichengreen *et al*. (2012, 2013) who identify these countries as nations that have reached a US$ 15.000 income per person in about 20 years (from 2005). At this point, the annual income growth per person is reduced to less than 3.5%. The middle-income trap occurs, typically, when manufacturing accounts for around 25% of GDP and the reduction operates mainly on the productivity factor. The 'middle-income trap' is associated with the transition that occurs in raw material export economies, when low cost labor and intensive exploitation of resources deplete their reserves. The initial phase (of rapid growth) if the process is the result of efficient reallocation of productive resources is supported by imported technology. However growth becomes slower when the reallocation of resources has a lower marginal productivity and imported technologies are not so efficient when it comes to increasing productivity.

In this context, investment in advanced human capital is essential to overcome the 'middle-income trap'. However, this investment must be profitable for future engineers and scientists. If this doesn't happen, the new professionals will migrate (the 'brain drain') to markets where their skills are better valued.

The problem of the education return risk has been studied and there is consensus that this risk diminishes investment in human capital (Ariga *et al*., 2005; Heckman, 2005; Brunello *et al*., 2006). On the other hand, it is foreseeable that in small and less developed regions, the variety and profitability of the demand for advanced human capital will be limited. Studies show that less demand for human capital will diminish the appeal for higher education, even when the number of talented potential students is comparable to that found in more developed regions. In addition, lower investment in human capital will lead to a more concentrated income distribution. (Iwahashi, 2007). Recent work on this matter suggests that the 'middle-income trap' may be associated with advanced human capital low density (Agenor and Canuto, 2015), which limits the economies of knowledge networks and generates an inefficient provision of work for highly qualified persons.

Within the context of the conditions described before, it is foreseeable that the training of engineers and scientists (in outlying areas) will face many of the problems already mentioned. Universities can help prevent conflicts of resource allocations by investing in advanced infrastructure, especially communications. They can also invest in the development of research and education networks. Finally, they should develop programs that raise the profitability of the scientific and technological work, the impact of which would strengthen intellectual property and would widen its commercial applications, as described by Cabrales (2008).

Certainly, the quality of the graduates will depend on the quality of the institution that receives them. The institutional quality is a very broad subject that tries to reflect the diverse rankings that some institutions elaborate. The oldest of these, the Academic Ranking of World Universities (http://www.shanghairanking.com), provides 34 indicators and 8 of them associated with available human resources (graduation and quantity). However, this analysis escapes the central purposes of this paper and is not discussed further.

Conclusions

The need to increase investment in human capital is not enough to get the pursued results of development. Indeed, engineering schools are the ones that must identify the constraints that are to be faced, so as to appropriately prepare engineers that are suitable for regional development. This is especially important when it comes to universities located in small regions that are far from industrial and economic centers in the world. This is particularly the case when one considers the productive and social environment of distant and small communities. Under those circumstances, it is expected that the production of scientific or applied knowledge (technology) will be lesser than the one obtained in large conglomerates with similar resources. In such a situation schools of engineering should seek mechanisms to compensate the disadvantages.

This can be achieved by intensifying linkages with enterprises, integrating collaborative networks with other schools, located in large cities, so as to develop internship programs in advanced technology companies. This policy can be supplemented by active technology transfer programs that contribute to the productivity of local enterprises.

The contribution to regional development may be weakened, due to the diversion of productivity in benefit of other regions or countries. Engineering schools of the regions must then develop two lines of work that can contribute to retain the benefits of the training in human capital that they perform in their regions or countries. A second line of work would be setting up production processes and/or R&D companies 'external to the region', in the region. This work would require an intense network of business links, and even economic incentives to attract strategic investments to peripheral regions. In both lines of work advanced specialization of engineering schools located in regions is appealing for companies and students.

In the long run, this recognition can transcend regional boundaries and facilitate the talented student recruitment and development of R&D projects. Schools of engineering should have an academic strategy that allows them to detect advantages in location, experience, or other specific conditions for the development of specialties of global reach.

Engineering schools must also be aware of the need for a strong connection between local regions needs and the 'state of the art' in the global scientific as well as the technological field. Thus, engineering schools should develop teaching activities focused on technological markets and programs for the training of skills in business ventures.

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