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Networks and Innovation: An Economic Model for European Regions (2002-2006) [1]

Authors: **Alfonso Badiola,** Associate Professor in Economics. Department of Economics, alfonso.badiola@unican.es, **Pedro Casares-Hontañón,** Associate Professor in Economics. Department of Economics, **Pablo Coto-Millán,** is Professor in Economic Analysis. Department of Economics., **Miguel Ángel Pesquera,** Professor in Transports. Department of Transport.

This research provides a new theoretical approach to innovation. The work also provides data processed in recent years (2002-2006) to regions of European regions, providing relevant empirical evidence on the relationship between Human Capital, Technological Capital, Innovation Capital, Network Capital and Innovation. In econometric modeling is considered especially for the regions of the European Union.

Keywords: *Innovation, European Union, Networks, Regions.*

Introduction

This research studies the role of Human Capital, Technological Capital, Innovation Capital and Networks Capital among the generation of innovation for each region. This is done through a general economic model composed of a basic equation that has as *exogenous variables* the Human Capital, Technological Capital, Innovation Capital and Networks Capital in order to explain innovation as *endogenous variable*.

The operation of the innovation generation process consist in that aside from the right combination of Human Capital, Technological Capital and Innovation Capital, there are other relational, cultural and institutional

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regional factors, this is what we will call Internal and Social Networks Capital, which affects to the understanding and support of Human, Technological and Innovation Capital generates in combination with them, innovation and acts at the same time generating economic effects over the output in terms of units, over the sales and the generation of employment.

The estimation of the model adopted is done by using econometric techniques from the available data concerning the variables involved regarding the one hundred nine regions of European Union.

It also compares the estimations of the model for various definitions of Human, Technological, Innovation Capital and Networks Capital, in order to analyze its impact on innovation.

Finally factors affecting the production of Human, Technological and Internal and Social Network Capital of the generation of innovation between the European regions are analyzed in detail and conclusions are extracted from the obtained results.

Literature Review

The role of Human and Technological Capital in the economic growth has been a topic of growing interest and debate between economics, geographers and other social researchers. Some of the most significant researches on these issues are listed below.

At the beginning of economic theory it was thought that the natural wealth of a region or country was the main determinant factor of growth. Subsequently, the natural resources were replaced by all kind of infrastructures, mainly of transport, made by man. With the industrial revolution and the subsequent theories of Solow (1956, 1957) technological progress becomes key explanatory factor. Nowadays, after the main contributions of Lucas (1988), we tend to think that the main factor of growth is the Human Capital, understood in a fairly broad sense. By these we mean that when talking about Human Capital we should not think exclusively in education, experience and skills of workers: we tend to consider the innovative capacity and human values. Even in the line of New Institutional Economics we can think of the quality of the institutions as a cause of the economic growth. Basically these are the factors of modern growth theory, especially that which has been developing since the mid-eighties until today.

For a long time, Technology and Human Capital have been considered

as the driving forces of economic growth. In this regard, Solow´s (1970) work stands out which highlights the relevance of the effect of technological change on the economic growth.

Jacobs (1961, 1969) studies were focused on the transference of knowledge in cities. In his reasoning, cities play a crucial role in the economic development through the interaction between people and the generation of new products and new technology.

Later, Romer (1986, 1987 and 1990) establishes the connection between knowledge, human capital and economic growth through his endogenous economic growth model, arguing that investments in Human Capital create externalities and increasing returns.

The seminal endogenous regional model of Lucas (1988) shows that cities act transferring knowledge and generating powerful human externalities that increase productivity and boost the economic growth.

Also, the connection between Human Capital and regional growth is supported by a large body of empirical evidences contrasted at national and regional levels. In the same thread of thought, recent researches (Barro (1991); Glaeser et al (1995); Glaeser (1998; 1999; 2000a y 2000b); Simon (1998), Glaeser et al (2001); Rauch (1993); Young (1998); Eaton and Eckstein (1997); Black and Henderson (1998); Simon (1998); Glendon (1998); and Shapiro (2006)) have empirically contrasted Lucas speculation, stressing the role of human capital and economic growth.

Berry and Glaeser´s (2005) work highlight the growing gap over the past decades in levels of human capital between regions among U.S.A.

Finally, Florida (2002a, b, c; 2005a and b; and 2006) has advocated the need to better understand the factors that generate innovation and creates a new concept of Creative Capital which is what enables territories to attract talent. He concludes that the Creative Capital operates more as a dynamic flow or a static stock.

This research argues that what are really relevant are the collaborative relationships that exist between universities, private companies and public administration. The university provides a grounding of Human Capital, scientifically trained, that adequately related to private enterprise can generate open innovation. However, it is still necessary the relationship between private companies and public administration to implement the discovery and become a reality. The link and liaison between the Human Capital and Technological is the Networks Capital, and that link is collaborative and appropriate when done

with creativity.

The Model

Towards a better understanding of the questions raised, we created a general model of generation of innovation for the European regions, in order to isolate and analyze the independent effects of Human Capital, Technology Capital, Innovation Capital, Networks Capital (Internal Networks Capital and Social Networks Capital) with the variable innovation.

A schematic representation of the general theoretical model of innovation is shown in Figure 1. The arrows identify the hypothetical structure of relationships between key variables.

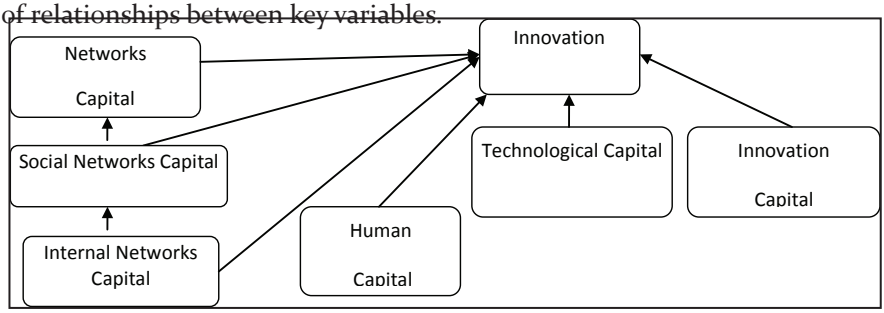

Figure 1: Structure of the relationships between Human Capital, Technological Capital Innovation Capital and Networks Capital with Innovation

Next, we will proceed to estimate the contribution of Human Capital, Technological Capital, Innovation Capital, and Internal and Social Networks Capital. We will use an aggregate production function which contains as a variable to explain the innovation or throughput and as explanatory variables four defined factors of production such as Human Capital, Technological Capital, Innovation Capital and Networks Capital. Such function will be of type:

$$f\left(y_1, y_2, y_3, y_4\right) = I = \tilde{a}\ \ y_1^{\acute{a}_1} y_2^{\acute{a}_2} y_3^{\acute{a}_3} y_4^{\acute{a}_4}; \left(\tilde{a} > 0\ \acute{a}_i > 0\right)\ ;\ (1)$$

In the previous equation (1) innovation is represented by I, and it is explained by four production factors as the effect of Human Capital,

represented by y_1, the investment in Technological Capital represented by y_2, the investment in Networks Capital which we will call the y_3 and finally investment in Innovation Capital which we will call y_4. The expression (1) will take now logarithms and obtaining the following specification:

$$\text{Log } I_{i,t} = \gamma_{1,0} + \alpha_{1,1} \text{ Log } y_{1,t} + \alpha_{1,2} \text{ Log } y_{2,t} + \alpha_{1,3} \text{ Log } y_{3,t} +$$

$$+ \alpha_{1,4} \text{ Log } y_{4,t} + \varepsilon_1 \; ; \; (2)$$

Where ε_1 represent the mistakes of the econometric estimation, while the rest of variables have been previously defined. Table 5 shows the results of the estimation of the equation (2).

The model adopted also enables the stimulation and analyze of the effects of internal (in house) and social relationships which are influenced by various institutional and regional cultural factors – for example, the university, the private companies and the empathy and support of the public administration, on the geographic distribution of innovation.

We have included the Innovation Index from Eurostat, this index is an indicator based on the number of patents registered and applied by the EPO (European Patent Office) per million of population with source Eurostat and Regional Innovation Scoreboard.

This research will use a set of econometric and statistical techniques, carrying out multivariate regressions of Human Capital, Technological Capital, Innovation Capital, Internal and Social Networks Capital and Innovation, in terms of number of patents in order to study the nature of the causal relations between the variables in the model of stages described above.

The Data of European Regions

The European Commission in order to track innovation in European regions has made a recent report (2009) which includes lots of indicators for the years 2004 and 2006 made with the same definitions and methodology. We take the data available from 2002 to 2006. The European regions are in alphabetical order as follows: Abruzzo, Alentejo, Algarve, Andalucía, Aquitaine, Aragón, Attiki, Auvergne, Basilicata, Basse-Normandie, Bayern, Berlin, Border-Midlend-and-Western, Brandenburg, Bremen, Bretagne, Bruxelles, Burgenland, Calabria, Campania, Canarias, Cantabria, Castilla-La-Mancha,

Castilla-León, Cataluña, Centre, Centro-(P), Ceuta, Comunidad-Valenciana, Corse, Drenthe, Dytiki-Ellada, Dykity-Makedonia, Eastern, East-Midlands, Emilia-Romagna, Extremadura, Flevoland, Friesland, Friuli-Venezia-Giulia, Galicia, Gelderland, Groningen, Hamburg, Ile-De-France, Islas-Baleares, Ionia-Nisia, Itae-Suomi, Karlsruhe, La-Rioja, Lazio, Liguria, Limburg-(Nl), Lisboa-E-Vale-Do-Tejo, Lombardia, London, Madrid, Marche, Mecklenburg-Vorpommern, Melilla, Mellersta-Norrland, Murcia, Navarra, Noord-Brabant, Noord-Holland, Nord-Pas-De-Calais, Norra-Mellansverige, Norte, North-East, Northern-Ireland, North-West, Oestra-Mellansverige, Övre-Norrland, Oberoesterreich, Overijssel, Pais-Vasco, Piemonte, Pohjois-Suomi, Principado-De-Asturias, Puglia, Madeira, Région-Wallonne, Rheinland-Pfalz, Saarland, Sardegna, Schleswig-Holstein, Scotland, Sicilia, South-East, South-West, Southern-And-Eastern, Stockholm, Sydsverige, Thueringen, Toscana, Trentino-Alto-Adige, Umbria, Utrecht, UUsimaa-(Suuralue), Vaeli-Suomi, Vaestsverige, Valle-D´aosta, Veneto, Vlaams-Gewest, Wales, West-Midlands, Yorkshire-The-Humber, Zeeland and Zuid-Holland.

Variables used in this model are the following:

= Dependent Variable: Innovation (Number of Patents)

The dependent variable used in the model to approximate of innovation, index of the number of EPO patents per million population with source in Regional Innovation Scoreboard.

Independent variables are the following:

= Indexes of Human Capital

It was considered in order to represent the Human Capital, as a traditional or conventional indicator of the Human Capital, measured as the average of the population with tertiary education per 100 population aged between 25 and 64 years with source Eurostat and other index of the participation in lige-long learning per 100 population aged between 25 and 64 years with source Eurostat and Regional Innovation Scoreboard.

= Indexes of Technological Capital

It includes a technology variable to account the independent effects of the technology in the regional innovation. The average of the indicators used to obtain the Technological Capital index: share of GDP in public expenditure on R&D source Eurostat and share of GDP in private expenditure on R&D source Eurostat.

= Index of Innovation Capital

It includes a variable to account the independent effects of the investment in innovation. The indicator used to obtain the Innovation Capital index is: percentage of total turnover in innovation expenditures (Non-R&D innovation expenditures) with source in Regional Innovation Scoreboard.

= Index of Networks Capital

Another set of explanatory variables correspond to the measures of Networks Capital, understood not only as reducing barriers for the entry of Human Capital, but the facilitation and collaborative support. Networks Capital among the regions and the concentration of these opening factors create an economic, social and cultural environment more open to innovation. For this variable a synthetic index of Networks Capital was used from the following two indicators: Sum of SMEs with intern innovation activities, with cooperation between workers and managers, in-house, measure by percentage of all SMEs (We will call Internal Networks Capital) and Sum of SMEs with extern collaboration with other companies, co-operating with others measure by percentage of all SMEs (We will call Social Networks Capital) with source Eurostat. All the variables has been normalized from 1 to 10. In Table 1 shows the variables and their descriptive statics.

Table 1: Variables and sample descriptive statics (2002-2006).

Variables	Mean	St. dev	Max	Min	Observations
Human Capital	5.164	2.073	10	1	545
Tertiary Education	5.223	1.858	10	1	545
Lifelong Learning	5.105	2.289	10	1	545

Technological Capital	4.324	2.073	10	1	545
Public R&D	4.356	2.234	10	1	545
Business R&D	4.292	2.234	10	1	545
Networks Capital	5.090	1.997	10	1	378
Internal Networks Capital	5.709	2.263	10	1	378
Social Networks Capital	4.471	1.731	10	1	378
Innovation Capital	5.142	1.846	10	1	198
Innovation (number of patents)	3.572	2.271	10	1	545

Source: Own elaboration.

Results to regions of European Union

Next we will proceed to estimate the equation (2) proposed in the model

Table 2: Results of the estimations of Equation (2)

	Ln (Innovation)	**Ln (Innovation)**
Constant	-3.383 (-8.592)	-3.121 (-8.925)
Ln (Human Capital)	0.469 (2.906)	0.486 (3.228)
Ln (Tech. Capital)	1.034 (26.47)	1.031 (26.43)
Ln (Networks Capital)	0.432 (3.632)	-
Ln (Internal Networks Capital)	-	0.187 (1.862)
Ln (Social Networks Capital)	-	0.281 (2.334)
Ln (Innovation Capital)	0.191 (2.906)	0.176 (2.541)
Number of observations	198	198
R2-Ajusted	0.932	0.932

Hausman	18.291	17.541

Source: Own elaborations. European Regions are others regions have been excluded due to missing data.

Some regions were excluded because there were no data available of some variables as seen in previous section. The estimates were made with panel data techniques with fixed effects. The results of the estimation of the equation (2) with panel data technical from the model adopted, relating to the Innovation (Number of Patents), are shown in Table 2.

From these results the following conclusions can be drawn:

A) In this case, as in the rest of the literature on Innovation, the variable that best approximates innovation is the number of patents.

B) The elasticity of the Human Capital and Innovation is significant and positive (0.469-0.486).

C) The elasticity of Technological Capital and Innovation is significant and positive (1.031-1.034).

D) The elasticity of Networks Capital and innovation is significant and positive (0.432).

E) The elasticity of Social Networks Capital and innovation is significant and positive (0.281).

F) The elasticity of Internal Networks Capital and innovation is significant and positive (0.187).

G) The elasticity of Innovation Capital (expenditures in innovation) and innovation is significant and positive (0.176-0.191).

H) Innovation is explained reasonably well by the four key variables – Human Capital, Technological Capital, Innovation Capital (expenditures in innovation), and Networks Capital (Internal and Social Networks Capital).

Conclusions

This research proposes the existence of a new drive of innovation and with it not only of the sales based on the accumulation of knowledge but in the collaborative relations between universities, companies and public administration.

This research analyzes the causes of innovation which are empirically contrasted for the case in all the regions of the European Union with availability

of dates.

The main conclusions of the modeling performed are as follows:

A) With our database of the European area regions we have found empirical evidences that the Human Capital.

B) Human Capital has a direct effect over the Innovation (Number of patents). Human Capital operates as a crucial intermediate variable in the process of innovation which connects the factors in house and outside of the enterprises with Networks.

C) Technological Capital or the technological platform has in this case, as in the traditional literature, an important role in generating innovation.

D) It is surprising the high explanatory power of the news variables: Internal Network Capital and Social Network Capital, defined here. It seems that collaborative relations between universities, private companies and public administrations, this is, the Internal Networks Capital and Social Networks Capital, are significantly associated with the generation of Innovation.

The analysis shows that the Networks Capital have positive and relevant role in the production of Technological Capital and Innovation. The Social Networks made collaborative relations are outside the market; however, they provide the greasing between the innovation as an idea and its practical implementation. Certain regional conditions of relational type seem to play a significant role and encourage the creation of an environment or habitat that cat link the Human Capital with the Technological Capital and generate innovation. The three factors of Human, Technological and Networks Capital do not operate in competition with each other, but they tend to act playing complementary roles in the process of generating innovation.

References

[1] Barro, R. J. (1991): "Economic Growth in a Cross Section of Countries", *Quarterly Journal of Economics*, 106(2): 407-443.

[2] Berry, C. R. y Glaeser, E. L. (2005): *The Divergence of Human Capital Levels Across Cities*. NBER Working Paper No. 11617. Chicago, IL: University of Chicago September 2005.

[3] Black, D., y Henderson V. (1998): "A theory of urban growth", *Journal of Political Economy* 107 (2): 252 – 84.

[4] Eaton, J., y Eckstein Z. (1997): "Cities and growth: Theory and evidence from France

and Japan", *Regional Science and Urban Economics*, 27 (4-5): 443–74.

[5] Florida, R. (2002a): *The Rise of the Creative Class. And how it's transforming work, leisure, and everyday life*. New York: Basic Books.

[6] Florida, R. (2002b): "The Economic Geography of Talent", *Annals of the Association of American Geographers*, 92(4): 743-755.

[7] Florida, R. (2002c): "Bohemia and economic geography", *Journal of Economic Geography*, 2: 55-71.

[8] Florida R. (2005a): *Cities and the Creative Class*. New York: Routledge.

[9] Florida R. (2005b): *The Flight of the Creative Class*, Harpers Business.

[10] Florida, R. (2006): "Where the brains are", *The Atlantic Monthly*, 298(3):34.

[11] Glaeser, E. L. (1998): "Are cities dying?", *Journal of Economic Perspectives*, 12:139–60.

[12] Glaeser, E. L. (1999): *The future of urban research: Nonmarket interactions*. Washington, DC: Brookings Institutions.

[13] Glaeser, E. L. (2000a): "The new economics of urban and regional growth". In *The Oxford handbook of economic geography*, ed. Gordon Clark, Meric Gertler, and Maryann Feldman, 83-98. Oxford: Oxford University Press.

[14] Glaeser, E. L. (2000b): "Cities and Ethics: An Essay for Jane Jacobs", *Journal of Urban Affairs*, 22:4: 473-494.

[15] Glaeser, E. L., J. A. Sheinkman, y Sheifer A. (1995): "Economic growth in a cross-section of cities", *Journal of Monetary Economics* 36:117–43.

[16] Glaeser, E. L., J. Kolko, y Saiz. A. (2001): "Consumer city", *Journal of Economic Geography*, 1:27–50.

[17] Glendon, S. (1998): "Urban life cycles", Working paper. Cambridge, MA: Harvard University.

[18] Jacobs, J. (1961): *The Death and Life of Great American Cities*, New York: Random House.

[19] Jacobs, J. (1969): *The Economies of Cities*, New York: Random House.

Lucas, R. E. (1988): "On the mechanics of economic development", *Journal of Monetary Economics*, 22, 1 (Julio): 3-42.

[20] Rauch, J. E. (1993): "Productivity gains from geographic concentrations of human capital: Evidences from cities", *Journal of Urban Economics*, 34, pp. 380-400.

[21] Romer, P. M. (1986): "Increasing returns and long-run growth", *Journal of Political Economy*, 94, 5: 1002-1037.

[22] Romer, P. M. (1987): "Crazy explanations of the productivity slowdown", NBER Macroeconomics Annual. 2: 163-202.

[23] Romer, P. M. (1990): "Endogenous technological change", *Journal of Political Economy,* 98, 5: S71-S102.

[24] Shapiro, J. M. (2006): "Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital", *The Review of Economics and Statistics*, Vol. 88(2): 324-335.
[25] Simon, C. (1998): "Human capital and metropolitan employment growth", *Journal of Urban Economics*, 43: 223 – 43.
[26] Solow, R. M. (1956): "A contribution to the theory of economic growth", *Quarterly Journal of Economics*, 70, 1: 65-94.
[27] Solow, R. M. (1957): "Technical change and the aggregate production function", *Review of Economics and Statistics*, 39: 312-320.
[28] Solow, R. M. (1970): Growth theory: an exposition, Oxford: Clarendon Press.
[29] Young, A. (1998): "Growth without scale effects", *Journal of Political Economy*, 106, 1: 41-63.