A KNOWLEDGE-BASED MODEL OF REGIONAL GROWTH

L.E Vila

B. Cabrer

J.M. Pavía

Universidad de Valencia

ABSTRACT

A two-equation dynamic panel-data model with fixed effects is used to analyse the relationship between knowledge creation and economic performance among 17 Spanish regions over time (1989-2001). In the model, productivity depends on new knowledge, technological change is achieved using R&D effort over existing knowledge, and external effects of both new knowledge are productivity are allowed. Estimates show, first, that regional innovation depends on regional R&D, on the amount of human and physical capital available in the region, and on innovation in other regions; and second, that regional productivity depends on regional innovation, on updated human capital in the region, and on productivity in other regions. The results imply, first, that efficiency gains at regional level may be achieved by investing locally in the creation of new knowledge, either technological or organisational; second, that innovation in a region may be promoted by locally using greater amounts of existing knowledge, as well as by increasing local R&D effort; and third, that locally generated innovation and efficiency gains may reach other regions.

1. INTRODUCCIÓN

In recent times, the levels of GDP per capita diverged across EU countries and often across regions within some countries, as was the case for Spain. These disparities were explained because of the fact that some economies, either at national or at regional level, were able both to increase the number of people working and improve their productivity, while others were not (Scarpetta et al., 2000). Over the 1989-2001 years remarkable increases both in the size and in the average educational attainment of the labor force were registered for Spain. Educational reforms, the rapid expansion of the higher education system, and the increasing participation of women both in post-compulsory education and the labor market played key roles. As a consequence, economic growth at national level was relatively high and persistent although its territorial distribution within the country was far from homogenous, leading to increasing disparities in wellbeing at regional level.

The relationship between knowledge, science, technology and productivity appear to have changed in the 1990's. Innovation, that is, newly achieved knowledge that is applied to production, is now considered more critical to success in business and, ultimately, to the growth of economies. Information and communication technologies play a capital role in facilitating the diffusion of technological and organisational developments. According to OECD (2000), technology and innovation are the main drivers of increased economic growth performance in developed countries. Increases in efficiency, measured as multi-factor productivity (MFP), are mainly the result of the application of new technology along with more efficient ways of organising production. In this environment, the role of knowledge creation and accumulation in explaining divergences in economic growth among countries or regions becomes prominent. The education of the labor force is at the root of both technological and organisational developments; additionally, the diffusion of innovation relates to the availability of a workforce with sufficient and up-to-date competences. In particular, higher education relates to labor productivity in several ways through innovation. First, a substantial proportion of the effort in both basic and applied research is done within higher education institutions. Second, the education system provides qualified labor for industry and service sectors, including those who will develop research activities. Third, higher education is more productive the more volatile the state of technology is.

Changes in the production process lead to increases in the demand for diverse types of highly qualified labor. The regional distribution of changes depends on the regional distribution of technological effort, which, in turn, relates to the supply of highly qualified labor. Consequently, regional divergences in income and wellbeing are likely to be explained in terms of regional patters of investment in new knowledge through research and higher education.

This paper aims at clarifying whether and how the creation and accumulation of knowledge in a region improve its economic performance through efficiency gains in the use of the available resources, which would ultimately result in faster economic growth and higher well-being. Section two provides background by summarising the key features of the new growth literature linking knowledge and economic performance. Section three specifies a dynamic two-equation empirical panel-data model for knowledge creation and its impacts on economic efficiency within a regional framework. Section four describes the data set and the choice of variables. Estimation results from the model are shown and discussed in section five. Finally, section six concludes.

2.- BACKGROUND

The mechanisms that channel the positive effects of education into economic growth have been analyzed for half a century (Temple, 1999). Initially, two separate strands of traditional economic theory approached, although with severe limitations, the economic role of knowledge. On the one hand, neo-classical growth theory described a firm's output as a function of two factor inputs, capital and labor, with knowledge operating typically as an exogenous force enhancing labor effectiveness. On the other hand, human capital theory predicted that increased knowledge makes individuals more productive, hence they will earn higher wages reflecting their addition to the firm's output.

Recently, new growth theories have bring together both neo-classical and human capital traditions by establishing a much richer framework to understand the mechanisms that channel the positive effects of knowledge creation and accumulation into efficiency, economic growth and wellbeing. Three main features can be found: first, the incorporation of human capital as factor input in the production function; second, the analysis of innovation and endogenous technological change; and third, as consequence of the other two, the consideration of diverse types of knowledge-related externalities.

Human capital has been included as factor input in three types of growth models: sources-of-growth models, Solow's augmented models, and endogenous growth models.

The sources-of-growth models may be typically represented as

$Y=AKaLbHg \qquad a+b+g=1$

where Y is aggregate output, A is MFP, K is capital stock, L is labor, and H is human capital. The model may be used to study the relative contribution of each factor to economic growth by estimating its parameters, as Barro (1991) proposed. Alternatively, by applying chosen parameter values to input and MFP growth rates it provides the basis for growth accounting exercises such as those in Denison (1967) and Maddison (1982, 1991).

Solow's neo-classical growth model may be augmented to include human capital as a third factor input giving the reduced production function

$Y=KaHb(AL)1-a-b$

where output Y depends on capital stock, K, human capital, H, and labor efficiency, AL. Solving the model for the equilibrium growth rate, Mankiw et al. (1992) showed that both physical and human capital investment rates are among the determinants of income growth.

Endogenous growth models consider human capital as an input factor that generates external effects. The seminal paper by Lucas (1988) represented the reduced production function for a firm j as:

$Yj=AKjbHj1-bHag$

where Ha is the average level of human capital across all firms and g represents the external effect of the average level of human capital in the economy influencing individual firms' output. External effects of human capital at industry, region or country levels have been also considered.

Sources-of-growth and Solow's augmented models treat human capital as a private good (that is, both rival and excludable), while endogenous growth models assume that human capital is only partially excludable. All of them, however, consider technological progress, i.e. the flow of newly achieved knowledge about technology, as an exogenously provided public good (non-rival and non-excludable), a rather strong assumption which precludes a better understanding of the economic role of knowledge. The creation of new technological knowledge requires resources to be specifically allocated to R&D activities whereby the new knowledge is generated. In other words, the creation of technological knowledge should be incorporated as an endogenous determinant in economic growth models. A body of literature focused on the economics of innovation offers the means to endogenize the creation of new tech-knowledge. The most prevalent model of technological change is the so-called knowledge production function, which can be written as

$$I = a\ Rb\ Hg$$

where I represents innovative activity, R represents R&D inputs and H stands for human capital inputs. Although the knowledge production function was initially applied to firms' behaviour (Griliches, 1979), empirical evidence was found to be stronger at broader levels of aggregation such as industries, regions or countries (Pakes and Griliches, 1984), which suggested the presence of knowledge-related spatial externalities. Consequently, growth models incorporating endogenous innovation most often assume that existing knowledge is a non-rival, partially excludable good that may generate external effects (Romer, 1986, 1990). Accordingly, the production function for new technological knowledge may be typically written as

$$I = a\ Rb\ \ Hg\ Zd$$

where the term Z represents the external effects at the appropriate level of aggregation.

3. EMPIRICAL MODEL SPECIFICATION

Economic theory suggests that regional economic performance is likely to be influenced by both the amount of existing knowledge and the flow of new knowledge available in the region. Additionally, knowledge-related inter-regional external effects may appear both in the creation of new knowledge and in the production of goods and services. Economies create and accumulate knowledge through a variety of activities including formal education, on-the-job training, learning by doing, trial and error, and scientific investigation. Indeed, the whole production system may be regarded at as knowledge in use: materials, processes, products, technology, infrastructures and organisations, all emerged from what people knew, thought of, found out, and built up or created. The distinction between the technological and the organisational components of knowledge in the economy is relevant to our purpose because these two components emerge from different activities and are accumulated in different ways. Technological knowledge emerges from research and innovation, and it is accumulated as physical capital. Organisational knowledge exists in people’s minds in terms of human ability, skills, competencies, and know-how. It emerges from people's education and experience, and is accumulated as human capital. The knowledge already existing in the economy is, in turn, a factor input for the creation of new knowledge.

Research and development activities generate new technological knowledge on the basis of existing organisational and technological knowledge. This newly achieved tech-knowledge will increase the amount of knowledge available for the future in two ways. First, it would be incorporated into the production process as productive innovation, thus increasing existing tech-knowledge; and second, newly achieved knowledge will be learned by people at schools and universities, thus improving future organisational knowledge.

Within this conceptual framework, we specify a two-equation dynamic panel-data model to estimate the influence of knowledge creation and accumulation on economic efficiency at regional level over time. We specify a dynamic equation for the production of new technological knowledge created in region i at time t ($N_{i,t}$). Assuming that knowledge creation depends on its own past values, ($N_{i,t-1}$), the factor inputs for the creation of new tech-knowledge are the effort explicitly devoted to generate it ($R_{i,t}$) and the amount of knowledge already used in the region. As pointed out, knowledge in use resides both in people, as organisational knowledge, ($H_{i,t}$), and in capital stock, as formerly achieved tech-knowledge, ($T_{i,t}$). Regional heterogeneity in the generation of new tech-knowledge is accounted for through the inclusion of a fixed regional effects term (θ_i). The possibility of external inter-regional effects in the production of new technological knowledge is allowed by including an additional regressor ($Z_{i,t}$) representing spatial diffusion of innovation. The techn-knowledge production equation is written as

$$N_{i,t} = \beta_1 N_{i,t-1} + \beta_2 R_{i,t} + \beta_3 H_{i,t} + \beta_4 T_{i,t} + \beta_5 Z_{i,t} + \theta_i + \xi_{i,t} \qquad \text{(Eq1)}$$

Next, we specify another dynamic equation for efficiency in the use of the available resources in region i at time t, ($P_{i,t}$). Assuming that regional efficiency depends on its own past value ($P_{i,t-1}$), efficiency gains emerge from the flow of newly achieved knowledge, both in its form of technological change or in its form of improved human capacities. Consequently, the factor inputs for efficiency at time t are the innovation locally generated in the previous period ($N_{i,t-1}$) and the new organisational knowledge available in the region ($G_{i,t}$). Regional heterogeneity in efficiency is accounted for through a term of fixed regional effects (ϕ). The possibility of external inter-regional effects in efficiency is allowed by including an additional term ($X_{i,t}$) representing the spatial diffusion of efficiency. The equation for productivity is written as

$$P_{i,t} = \gamma_1 P_{i,t-1} + \gamma_2 N_{i,t-1} + \gamma_3 G_{i,t} + \gamma_4 X_{i,t} + \phi_i + \varepsilon_{i,t} \qquad \text{(Eq2)}$$

The model defined by equations 1 and 2 displays some empirically relevant features that will be addressed in the next section when discussing the estimation strategy.

4. DATA PANEL, ESTIMATION STRATEGY AND RESULTS

The model described in section 3 is applied to a 17-region, 13-year panel data set to study the influence of knowledge creation and accumulation on economic efficiency at regional level in Spain over the 1989-2001 period. Regional innovation (Ni,t) is measured by the number of granted patents per worker in region i at time t. The number of patents proxies for the amount of new tech-knowledge locally created in the research process, although it does not provide a complete count of regional technological innovation. Regional efficiency (Pi,t) is measured as MFP in the region representing overall efficiency in the use of the available resources. For empirical purposes it is defined as the fraction of economic growth that remains unexplained by the increases in capital stock and in the number of workers, so in this paper MFP has been calculated from Solow's residual within a sources-of-growth accounting framework with capital stock and labor as factor inputs. The fraction of regional GDP allocated to research and development activities (Ri,t) measures the local effort explicitly devoted to creation of new tech-knowledge in the region. The proportion of workers with post-compulsory education, and the ratio capital per worker account for the amount of already existing organisational (Hi,t) and technological knowledge (Ti,t), respectively. New organisational knowledge in the region (Gi,t) is measured as the increase in the fraction of higher education graduates among the workforce as a proxy for the change in aggregate local labor quality, reflecting the newly achieved knowledge learned at universities that fresh graduates bring into production every year. The external effects in the production of new knowledge (Zi,t) and efficiency (Xi,t) are built to capture geographical spillovers by weighting a matrix of contiguity among regions with regional innovation and regional productivity, respectively.

The two-equation dynamic panel-data model described above displays some features that are relevant for estimation purposes. First, the equations are not independent from each other since the dependent variable in Eq1 enters as a lagged regressor in Eq2. Second, the dependent variable in Eq1 is non-negative. Third, each equation has a lagged value of its dependent variable as a right-hand side regressor, so both ordinary least squares (OLS) and least squares in deviations (LSDV) estimates of the fixed effects model would be biased and inconsistent because of the correlation between the lagged value and the corresponding error term. Non-independence is relatively easy to address since the model may be solved recursively. Taking advantage of its non-negative character, innovation may be pre-determined by ML asymptotically efficient estimation of a censored normal model (TOBIT) and the lagged prediction used as a regressor in the estimation of Eq2. This recursive estimation strategy, however, does not address the correlation between the lagged value of the dependent variable and the error term in Eq2. The solution in this case is to instrument the variable correlated with the error term with a suitable instrument (correlated with the dependent variable and not correlated with the error term). The optimal instrument matrix for GMM estimation of the fixed effects model with lagged dependent variables as explanatory depends on:

Whether the other explanatory variables in the equation are or not correlated with the fixed effects

Whether they are predetermined or strictly exogenous

Optimal GMM estimators for each equation may be built up by taking into account all the available moment-restrictions in the definition of the instrument matrices in each case. In our model, N is a predetermined regressor, while R, H, T, G, X and Z enter as exogenous, and that they are not likely to be correlated with the fixed regional effects of the corresponding equations.

Estimation of Eq1 and Eq2 is carried out using two different estimation strategies. The first one uses TOBIT estimation for Eq1 and LSDV estimation for Eq2. The second strategy estimates both equations through GMM optimal estimation. Table 1 summarises the Tobit-LSDV and GMM estimation results of the two-equation dynamic panel-data model specified in section 3. The general results confirm that all the explanatory variables included in the model have significant effects, with the predicted signs, irrespectively of the estimation procedure used.

Table 1. Tobit-LSDV and GMM estimation results of the model

	Tobit - LSDV estimation		GMM optimal estimation	
Equation 1: Innovation	*Coeff.*	*z-stat*	*Coeff.*	*z-stat*
Human capital	0.322	*3.0*	0.337	*3.4*
Capital stock per worker	0.446	*8.2*	0.471	*9.5*
R & D effort	1.744	*2.2*	1.648	*2.2*
Spatial diffusion	0.009	*2.1*	0.010	*2.6*
Innovation (t-1)	0.291	*5.1*	0.259	*5.1*
Equation 2: Efficiency				
Innovation (t-1)	4.050	*4.4*	3.910	*5.9*
Increase HEG	5.359	*2.7*	5.249	*3.5*
Spatial diffusion	0.156	*3.9*	0.161	*5.5*
Efficiency (t-1)	0.682	*11.8*	0.703	*16.1*

Results from Eq1 reveal that, in a region, the creation of new tech-knowledge depends on both the effort devoted to develop it and on the amount of knowledge already existing in the region. Regional innovation depends positively on the effort locally devoted to the creation new tech-knowledge, represented by R&D expenditure. Moreover, innovation depends positively as well on the amount of knowledge, both organisational, represented by human capital, and technological, expressed by the ratio capital per worker, already used in the region. Besides, innovative activity in a region benefits from positive external effects from innovation in other regions. Additionally, the dynamic part of the model reveals that regional innovation depends significantly on its own past value.

Coefficient estimates from Eq2 show that regional efficiency gains emerge from newly achieved knowledge, both in its technological and organisational components. Interpretation of results is straightforward: regional efficiency depends positively on regional innovation in the previous period and on the improvement in local labor quality. Besides, efficiency in a region benefits from positive external effects from efficiency gains in other regions. Additionally, the dynamic part of the model shows that regional efficiency depends significantly on its own past value as well. GMM optimal estimation of both equations in the model does not alter the fundamental results since differences between coefficient estimates are quite small in all cases. However, there is some evidence of systematic reductions in the standard errors of GMM coefficient estimates for Eq2, thus implying larger values for the corresponding z-statistics. This is explained because the Tobit-LSDV estimation of Eq2 includes instruments for innovation but not for the lagged dependent variable, which remains correlated with the error term. Consequently, an extra result is that GMM estimation of both equations appears to be more efficient that our initial Tobit-LSDV estimation strategy.

5. CONCLUSIONS

The analysis conducted in this paper highlights the relevance of local knowledge creation and accumulation in explaining differences in growth rates among Spanish regions. During the 1989-2001 period, economic growth at national level was relatively high and persistent, fostered by remarkable increases both in the size and in the average educational attainment of the labor force. However, its territorial distribution within the country was far from homogenous, leading to increasing disparities in wellbeing at regional level. Regional disparities in R&D and in the supply of educated labor, which translate into inequalities in the amount of available knowledge among regions, help to explain regional disparities in the creation of new knowledge, which, in turn, are at the root of divergent economic growth patterns among Spanish regions.

Efficiency gains at regional level appear as the result of regional knowledge creation, both in its technological form, i.e. technological innovation, and it its organizational form, i.e. increased labor quality. Regional technological innovation, in turn, is the result of applying R&D effort over the stock of technological and organizational knowledge already available in the region. Thus, regional advances in efficiency would require regional advances in the creation of technological knowledge, which in turn depends on R&D effort and on the accumulation of both technological and organizational knowledge, and on improved higher education of the regional labor force, as a primary source of new organizational knowledge. Those regions that do not generate new knowledge rapidly enough are at risk of being left behind in the process of development. The lack of a sufficient supply of highly educated workers in some regions may operate as a barrier both to technological innovation and the creation of organizational knowledge. Regional policies must be favorable to improve the educational level of the labor force as a means to promote the collaboration between science and industry in the creation of new knowledge. Additionally, the results highlight the need of local public support for basic scientific research and higher education to increase the flow of new technological and organizational knowledge at regional level. Regions differ in their ability to adapt to new economic conditions, therefore educational and research policies at regional level appear as key instruments to ease the transition not only directly, but also indirectly through the spatial diffusion of its effects, so less developed regions may share the benefits from the new knowledge already generated by other regions.

6. REFERENCES

Aghion, P. & Howitt, P. (1992), "A model of growth through creative destruction", Econometrica, 60, 323-351

Barro, R.J. (1991), "Economic growth in a cross-section of countries", Quarterly Journal of Economics, 106, 470-443

Denison, E.F (1967), Why Growth Rates Differ. The Brookins Institution,.Washington D.C

Griliches, Z. (1979), "Issues in assessing the contribution of R&D to productivity growth", Bell Journal of Economics, 10, 92-116

Lucas, R.E. Jr. (1988) "On the mechanics of development", Journal of Monetary Economics

Maddison, A. (1982): Phases of Capitalist Development. Oxford University Press, Oxford.

Maddison, A. (1991), Dynamic Forces in Capitalist Development. A Long-run Comparative View. Oxford University Press, Oxford.

Mankiw, G., Romer, D. & Weil, D (1992), "A contribution to the empirics of economic growth", Quarterly Journal of Economics, 107, 407-438

Pakes, A. & Griliches, Z. (1984), "Patents and R&D at the firm level: A first look", in Z. Griliches (ed.), R&D, Patents, and Productivity. University of Chicago Press, Chicago:

OECD (2000): A new economy? The changing role of innovation and information technology in growth. OECD. Paris.

Romer, P.M. (1986) "Increasing returns and long–run growth", Journal of Political Economy, 94, 1002-1007

Romer, P.M. (1990), "Endogenous technical change", Journal of Political Economy, 98, 71-102

Scarpetta, S., Bassanini, A.; Pilat, D. & Schreyer, P. (2000), Economic Growth in the OECD Area: Recent trends at the aggregate and sectoral levels. OECD Economics Department Working Papers, OECD, Paris

Solow, R. (1956), "A contribution to the theory of economic growth", Quarterly Journal of Economics, 70, 65-94

Temple, J. (1999), "The new growth evidence", Journal of Economic Literature, 37, 112-156

Van Marrewijk, C., De Vries, C.G. & Withagen, C. (1992), "Optimal localised production experience and schooling", International Economic Review, 33, 91-110