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Modeling of State Innovativeness Based on Space-time Models

1. Macroeconomic Modeling Issues

With macroeconomic data available, the issue of insufficient number of observations necessary for econometric modeling frequently occurs. This kind of data is usually described in terms of annual frequency and the possible replacement thereof with quarterly information brings about the need to consider the seasonal variations, which in case of the questions we focus our interest on is practically unrealizable (i.e. the data related to the endogenous variable). The prolongation of several observations is made difficult for the following reasons:

- the lack of appropriate information,
- the territorial and administrative changes (this concerns the Central and Eastern Europe countries, in particular),
- the structural and technological changes.

When the information available on the formation of the phenomenon examined in a particular population is too scarce, one may expand it by the information on the same phenomenon for another population of a similar nature. Such test would be cross-sectional in this case (the same variables for various objects, e.g. countries) within the same time unit or cross-sectional-time when the data are additionally related to several periods.

The purpose of this paper is to present the possibility of using such models in examining the innovative activity.

The econometric analyses concerning the Central and Eastern Europe more and more frequently use the data on a group of countries of similar development tendencies, similar histories and aspirations for the future[1]. The patent related activity was used in order to examine the innovative activity . The measure of such activity can be the number of patents filed by the residents or non-residents of a particular country. For better comparability the figures are related to the number of inhabitants, the number of professionally active people or the area occupied by a particular country. In the 1980's such data were gathered basing on the different criteria of the two different political block countries existing in Europe at the time. It is since the 1990's only that we possess information systemized, according to the same criteria indicated by the World Intellectual Propriety Organization.

2. Space-Time Models

A typical method of using the space-time models is the single-equation, single-factor econometric model estimated in virtue of panel data, in the following form[2]:

$$y_{it} = \alpha + X_{it}^{T}\beta + u_{it} \quad \text{for} \quad i = 1,\dots,N,\ t = 1,\dots,T, \tag{1}$$

of which:
i – means an object (e.g. a country),
t – time (e.g. years),
$\boldsymbol{X^{T}_{it}}$ – is a vector of observations on explanatory variables with K coordinates,
α – is an absolute and invariable term in time and space,
u_{it} – is a random component divided into two groups, $u_{it} = \mu_t + v_{it}$, μ_t – reflects the non-observable and regression effect, not included in the equation and resulting from affiliation with the i-th group.
v_{it} – the remaining part of the random component.

In case the quantity of the objects is large, the application of the above methods is disputable as it requires the inclusion of additional artificial variables in the regression equation, which in consequence means the loss of degrees of freedom. Furthermore, when the number of observations for the data possessed does not grow in time, then estimator α and estimator μ will become incompatible. We solve the problem assuming that μ_i is a random variable, i.e., for example: $\boldsymbol{u_j = Z_\mu \mu_j + v_j}$. In this case we encounter a model with decomposition of the random component. We may similarly proceed in case of a two-factor model, where

$$\boldsymbol{u_j = Z_\mu \mu_j + Z_\lambda \lambda + v_j}.$$

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[1] This approach can be found in: Radosevic, Auriol (2001) and other works by this group of authors.

[2] More details on this subject: Dańska (2000).

The balanced data obtained permit, in addition to the said decomposition of the random component of the absolute term, to differentiate the structural parameter values for the individual variables in the test (Greene (2000)). It is assumed that the parameter value is composed of the value typical for all the objects and the value characteristic for the individual object:

$$Y_i = X_i\beta_i + \xi_i \tag{2}$$

Therefore, if: $\beta_i = \beta + v_i$ then:

$$Y_i = X_i\beta_i + (\xi_i + X_i v_i) = X_i\beta + w_i \tag{3}$$

The methods used in the estimation process are similar to those of the random component decomposition. Such methods, in addition to the selection of start levels of a particular phenomenon, permit to specify the individual characteristics of the particular objects grouped in the test. In our case, due to the vast complexity of calculations and, most of all, the problems resulting from having a non-balanced test, this method cannot be used.

In modeling with the use of space-time data, due to the differentiation of artificial variables responsible for the effects specific to individual objects, a series of tests is applied to check the total significance thereof. The most popular ones are: Chow's F-test, the Breusch-Pagan Lagrange multiplier test, the Hausman test.

There are two options to be applied in case of the data we have:

- to build a model based on a mixed test (space-time), non-balanced (where the length of time series varies from object to object),
- to build a model based on a balanced test – supplementing the data by the sectional method or by means of estimated trend equations.

Principally, it frequently appears that the parameters being the fragments of an absolute term decomposed are in some cases statistically insignificant. In such situation we replace the significant parameters with zero-one variables and proceed as in case of typical econometric models.

Originally, the space-time model proposed for estimation in the paper was to use the data on 22 countries throughout the period of 19 years: 1981-1999. The selected countries are the European OECD members. Those countries were expected to provide comparable data, necessary to estimate the proposed model's parameters. Despite the immense pressure on collecting comparable information for the recent years, for some countries (e.g. Norway, Greece) the data are collected in time intervals, longer than annual, which dramatically restricts the test, thus impeding the comparable time analysis. In case of new OECD members, such as Poland, Czech Republic or Hungary, the data that interest us refer to the period since their admission.

3. Structure of the Space-Time Activity Model

In case of building a space-time model, the first stage shall be the examination of the spatial heteroscedasticity for all the countries under consideration (Zeliaś (1991)).

At the preparatory stage the error correction model based on the data of 22 countries was proposed. The model – a test only – was built of one equation only:

$$\begin{aligned}\Delta Nlf_{it} &= \alpha_{i0} + (\alpha_1 - 1)(Nlf_{t-1} - \delta_1 GDPlf_{t-1} - \delta_2 Glf_{t-1} - \delta_3 Rlf_{t-1}) + \\ &+ \gamma_1 \Delta GDPlf + \gamma_{2\Delta} Glf + \gamma_3 \Delta Rlf + \xi_{it}\end{aligned} \tag{4}$$

of which:

Nlf_{it} - number of patent applications filed by non-residents in terms of one thousand labour force in a given period **t** for a given country **i**,

Plf_{it} – number of patent applications filed by residents in terms of one thousand labour force in a given period **t** for a given country **i**,

Glf_{ti} – gross expenses on R&D activity in a given period **t** for **i-th** country in terms of one thousand labour force,

$GDPlf_{ti}$ – value of GDP in USD stable prices from year 1995 according to purchasing power parity in terms of one thousand labour force for the **i-th** country in period **t**.

The model obtained is characterized with matching on the level: $R^2 = 0{,}68$, with the lack of auto-correlation and with the significance of selected decomposed absolute terms only. For the other (insignificant) terms, we apply the general absolute terms. It is worth mentioning that the application of the ECM structure, in most cases releases us from the possible non-stationarity of the processes examined and in addition, does not eliminate drawing conclusions on the existence of long-term dependencies (Welfe (2000)).

In consequence of the results obtained, concerning in fact, the research on the innovative absorbability, the construction of another model was suggested. The proposed model is composed of four recurrent equations. The first makes the level of economic development measured by GDP dependent on the investment expenses on fixed assets in the past, the level of the innovative activity in the past and the number of population.

The second equation describes the impact of economic growth on the expenses on the R&D activity. The gross expenses on research-development activity were considered the endogenous variable.

The third equation presents the impact of material and human capital on the potential innovative absorbability. The number of patents filed by non-residents during year t per the number of people professionally active was assumed as the potential innovative absorbability index.

Table 1. The values of structural parameter assessments including the levels of rejection of the hypotheses on significance

Parameter	Parameter estimate	T - statistics	Rejection level
α_{i0}	1.20	2.01	0.045
α_1-1	-32.77	-3.14	0.002
δ_1	-1163.63	-3.02	0.003
δ_2	67.68	3.14	0.002
δ_3	0.24	13.60	0.000
γ_2	-15.19	-3.23	0.001
γ_3	9.27	2.04	0.042
Austria	2.90	2.48	0.014
Denmark	3.21	2.53	0.012
Finland	3.03	2.99	0.003
Germany	2.75	1.92	0.056
Iceland	5.92	5.59	0.000
Ireland	2.12	1.78	0.075
Norway	2.16	2.03	0.044
Slovenia	3.75	3.12	0.002

Source: own calculations.

The fourth equation describes the innovative activity measured by the number of patents filed by the residents, converted into the number of people professionally active. The proposed explanatory variables were as follows: index of potential innovation absorbability determined in the second equation, the workforce resource measured by the number of people professionally active and the expense structure on the R&D activity presented as enterprise expense share in the total expenses on R&D (the only variable that was not related to the number of people professionally active).

The proposed number of people professionally active was the reference point in the model. Such model should provide information on the innovative activity of the part of society responsible to the greatest extent for creating the innovation and building of GDP. It is the professionally active population that actively participates in the R&D activity and the further stage of the innovation process – production. This model should in fact be built based on the logistic function (Chart 1) that reflects the examined dependencies to the nearest proximity. However, regarding the facilitation of the estimation and verification processes, it was assumed – truly – that the examined countries were in phase one, i.e. that of exponentially growing logistic function. In the case of the analyzed data, the exponential function as seems to be more appropriate than the others.

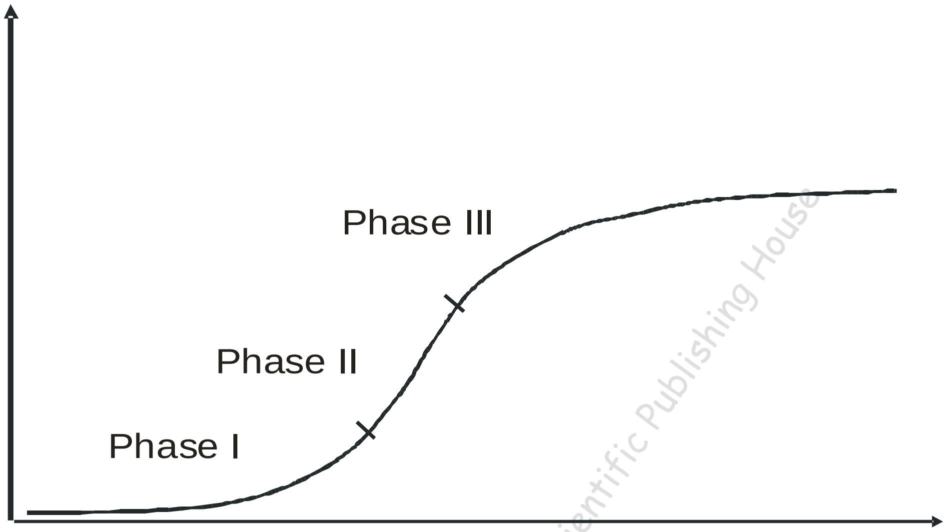

Fig. 1. Three phases of logistic function
Source: own calculations

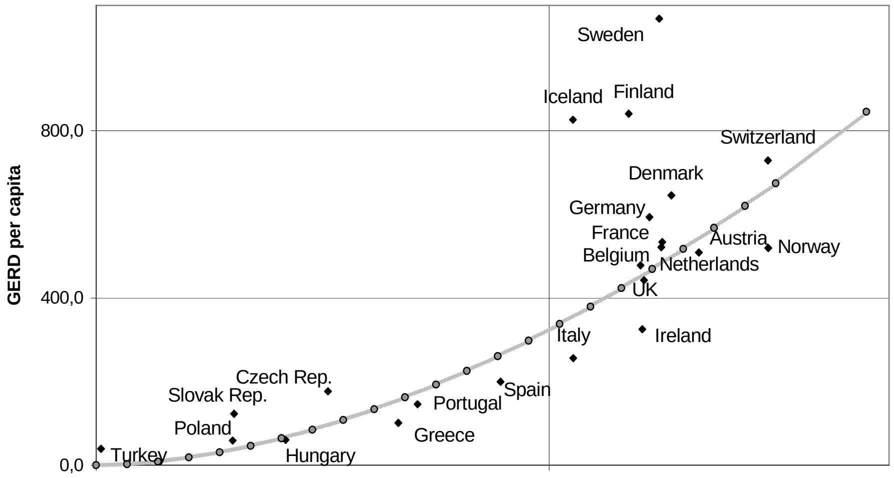

Fig. 2. Outlays on R&D per capita and GDP per capita in 2002 in some OECD countries (PPP in USD at 1995 prices)
Source: own calculations on the basis of OECD data

Thus the model was approximated by the power functions and after finding bilateral logarithm, has the following form:

$$\begin{aligned} \log GDPlf_{it} &= \alpha_{i1} + \beta_1 \log Plf_{it-1} + \beta_2 \log INWlf_{it-1} + \beta_3 \log P_{it-1} + \xi_{it} \\ \log Glf_{it} &= \alpha_{i2} + \beta_4 \log GDPlf_{it} + \xi_{it} \\ \log Nlf_{it} &= \alpha_{i3} + \beta_5 \log Glf_{it} + \beta_6 \log Rlf_{it} + \xi_{it} \\ \log Plf_{it} &= \alpha_{i4} + \beta_7 \log Nlf_{it} + \beta_8 \log Lf_{it} + \beta_9 \log BG_{it} + \xi_{it} \end{aligned} \quad (5)$$

The model was extended by the following variables:
$INWlf_{it-1}$ – investment outlays on fixed assets in terms of one thousand labour force in a given period **t** for a given country **i**,
P_{it} – number of peoples in thousands in a given period **t** for a given country **i**,
Rlf_{ti} – number of researchers in R&D sector in terms of thousand labour force in a given period **t** for **i-th** country,
LF_{it} – number of labour force in thousands in a given period **t** for a given country **i**,
BG_{it} – share of business in R&D sector financing in a given period **t** for **i-th** country.

The above approaches related to space-time modeling assume that:

1. The innovative activity for the particular countries is reflected in the number of patents filed within their territory by resident inventors.
2. The patent activity depends on the expenses on the R&D activity, mainly by the sector of enterprises, the number of people forming the gross national product and the level of potential innovative absorbability determined by the transfer of scientific and technological knowledge expressed by the number of patents filed within the territory of a particular country by non-residents.
3. The expenses on the R&D activity are directly stimulated by the growth of GDP.
4. The potential innovative absorbability depends on the possibility of knowledge processing, namely the academic-research human resources and the possibility of funding the R&D activity.
5. The dynamics of patent activity development in various countries is close to the pace of growth, however, its “starting point” is different for economies with various grades of development. It is the consequence of the economic potential and absorbability of the scientific – technological knowledge inflowing from outside.

In virtue of the above assumptions, a model based on the ECM structure was also built.

4. Summary

The presented above methods of space-time data application indicate their extensive usability. The possibilities of using this type of information, due to the higher frequency of data occurrence for specifications of various groups of countries or regions is not to be ignored. If we have space-time data in the process of preliminary forecasting the method of forecasting based on space-time analogies may also be used.

The preliminary results of models built according to the structure presented gave very good results. Furthermore, the application of dynamic econometric methods – in case of ECM – allow for the indication of both short-term and long-term relations between the categories examined.

References

Dańska, B. (2000), *Przestrzenno-czasowe modelowanie zmian w działalności produkcyjnej w Polsce, Zastosowanie modeli panelowych*, Absolwent, Łódź.

Greene, W.H. (2000), *Econometric Analysis*, Prentice –Hall International, Inc, London.

Radosevic, S., Auriol, L. (2001), *Patterns of Restructuring in Research, Development and Innovation Activities in Central and Eastern European Countries: an Analisis Based on S&T Indicators, School of Slvonic and eastern European Studies*, University College London, BA half course unit, London.

Welfe, A. (2000), *Gospodarka Polski w okresie transformacji*, PWE, Warszawa.

Zeliaś, A. (1991), *Ekonometria Przestrzenna*, PWE, Warszawa.