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# Investigating Externalities of Knowledge Spillover among Selected European Countries

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## Abstract

Generally, knowledge spillovers result in the creation of new knowledge, increased competitive advantages, and economic cooperation. Since the investigation of spillover flows among countries is considered to be highly important, in this study, knowledge spillovers and its resulting externalities were considered among a number of selected European countries during 1995 to 2011 using spatial econometric analysis. The results indicated an indirect effect and positive feedback caused by changing human development index, research and development expenditure, and knowledge-bearing imports, which confirmed the existence of spillovers and adsorption capacity in this region.

**Keywords:** Externality, Knowledge Spillovers, Spatial Econometrics

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## Introduction

Knowledge and technical development are among the principle resources of dynamism in economic growth models. Therefore, patent activities include use, application, and transfer of scientific and technical knowledge in problem solving and this knowledge is different from the information which is conventionally applied. On the other hand, knowledge transfer occurs via movement of skilled labor, simulation and reverse engineering by local firms, and increasing competition and commercial communication between domestic and international firms; however, such transfer is limited by the adsorption capacity of the host country via various channels. This capacity provides an opportunity for learning and applying knowledge. Furthermore, geographical distance can facilitate or limit knowledge transfer; this distance is specifically important in knowledge transfer, because source countries are looking for the destination countries that, beside structural similarity, have minimum geographical distance from them. Thus, by the formation of a knowledge life cycle between the source and destination countries, both of them could benefit from this knowledge transfer with minimum cost. This cycle indicates a situation in which a foreign country transfers a less sophisticated knowledge to a domestic country. In this case, foreign and domestic countries are called source and destination countries, respectively. At the next stage, knowledge of the foreign country is combined with the domestic technology to generate new knowledge; then, it is returned to the foreign country. In this case, positions of source and destination countries are changed. In other words, domestic and foreign countries are called source and destination countries, respectively.

On the other hand, not only knowledge spillovers are not directly observable, but also their transfer is accompanied by some externalities which might have positive or negative effects on the economic growth and development. This article was aimed to investigate the nature of these externalities using intra- and inter- regional patent responses to the changes in the inputs of knowledge production function. Therefore, it is necessary to study the patent response of each region and other regions to changes in inputs of every region and the neighboring areas. This response indicates Marshall-Arrow-Romer (MAR) externalities. Based on MAR perspective, spillovers occur among similar units with sharing common knowledge; yet, on the opposite side, there are Jacob's externalities among complementary units. Therefore, the regions with various products must create more patents. Furthermore, Jacob's externalities are decreased with more increased distance compared with MAR externalities (Autant-Bernard and LeSage, 2011). Thus, in this study, direct and indirect effects on patent were investigated, which resulted from changing the inputs of knowledge production. Therefore, in order to investigate the externalities resulting from knowledge production inputs, research literature and model description are presented in Sections 2 and 3, respectively. In addition, model estimation is presented in Section 4 and conclusions are delivered in the final section.

## Literature

Considering the importance of technology spillover in international economy, numerous studies have been conducted on the presence and efficacy of technology spillovers in different time periods and using different methods. In this section, a quick review of the available research on technology spillover is presented. In this regard, Anselin et al. (1997) investigated spatial spillovers among academic research and patent and used data from 29 states in the USA in 1982. They concluded that there was weak evidence on spillovers among universities and research institutes inside the states; but, the resulted externalities went beyond the borders. Also, they found a correlation between academic studies and patent activities in the private sector along with externalities. Paci and Usai (2000) studied knowledge spillovers and geographical distribution of patent using data from 85 industrial sectors in Italy between 1990 and 1991. Results demonstrated spatial correlation in the distribution of patent activities and positive influence of industrial sectors from similar industrial sectors in the neighboring regions. Their analysis showed two externalities in this study. Fischer and Varga (2003) analyzed knowledge spillovers from research activities in scientific centers to high-technology industries in 72 regions inside Australia and used data related to 1991. The results indicated the presence of intra-regional spillovers; however, some externalities were produced which were smaller than MAR ones. Moreno et al. (2003) conducted a study entitled *"Spatial spillover, patent activity, and role of knowledge production process"* using data from 138 regions in 17 European countries between 1978 and 1997. They found a significantly positive spatial auto-correlation in patent; i.e. knowledge production in the studied region was influenced by spatial spillovers which resulted in increased patent activity in other regions. The most important effective factors for patent generation were international research and development expenditure. Driffield and Love (2003) studied direct foreign investment, technology source, and reverse spillovers in UK industries; by focusing on 1984-1992, they found that the technology made by spillovers in domestic firms spilt over to foreign firms; but, effect of these spillovers was limited to developed sectors. Nonetheless, both sides benefited from these spillovers. Also, they found that technology spillovers were influenced by spatial concentration of industries. Bernard and LeSage (2011) investigated knowledge spillovers using spatial econometric analysis models and data from 1992 to 2000. They stated that estimating spillovers, regardless of spatial dimension, can be biased and inconsistent; accordingly, they applied spatial TOBIT method and concluded that the biggest direct and indirect effects of technology spillovers in 94 Asian regions were related to research and development activities of private sector; these externalities decreased with distance from the source and the results referred to optimal regional strategies.

## Model description

In this study, endogenous growth model was used instead of exogenous growth model, since theory of exogenous growth model states that capital flows from countries with low efficiency to those with high efficiency; however, studies have shown such a flow and confirm capital transfer from poor to developed countries. In fact, the reason can be found in endogenous growth models. In endogenous growth models, the unanimous view is that accumulation of physical capital does not make countries richer, but human capital is placed beside physical capital and a ground is developed for the technology formation and its absorption capacity via research and development department. In this regard, Mingyong et al. (2006) applied Romer's (1990) model to study technology spillovers and stated that production was made using a large number of incomplete alternative inputs, since technical process is originated from the invention of new inputs via research and development activities. Two foreign and domestic countries are thus considered. In the domestic country, economy is composed of three parts of research and development, intermediate goods, and final goods.

For final goods, good y is produced under perfect competition and the production function is as follows:

$$Y = A\, H_y^{\alpha} \left[\int_0^N x_i^{\beta}\, di + \int_0^{N^*} x_{i^*}^{*\beta}\, di^*\right] \quad \alpha,\beta > 0\,, \alpha+\beta = 1 \tag{1}$$

where A, $H_y$, $x_i$, and $x_i^*$ are total productivity level, human capital used for final goods, and numbers of N intermediate domestic and foreign inputs denoted by i, respectively. N and $N^*$ indicate the number of domestic and foreign intermediate inputs, respectively.

Intermediate goods are invented or completed in research and development department and are then purchased from two domestic and foreign producers. Production in research and development department depends on international spillovers of research and development through commerce, human capital investment in this department, and technical knowledge of domestic country. Since technical knowledge is shown by different variables of capital goods, developing plans for answering new needs of domestic country can be defined as:

$$N^{\bullet} = \delta\, H_{\mathrm{N}}\, [\mathrm{N} + \mathrm{G}(\mathrm{D},\mathrm{H}) N^*] \tag{2}$$

where $\delta$, $H_{\mathrm{N}}$, and H are a productivity constant, amount of human capital used in research and development department, and total amount of human capital, respectively, which indicates the constant amount of knowledge and skill in economy ($H=H_N+H_y$). Also, $\mathrm{G}(\mathrm{D},\mathrm{H})$ shows adsorption capacity, which is determined by total domestic human capital and extent of economy openness so that $D\epsilon(0,\infty)$. For intermediate goods, after the development or invention of a project, an intermediate firm buys the project and produces the inputs under perfect competition. For the sake of simplicity, it is assumed that intermediate inputs are spent on the production of a unit of Y.

### *Market balance*

Price of product Y is considered one. $W_{\mathrm{H_y}}$ and $\mathrm{W}_{H_{\mathrm{N}}}$ are the payments of human capitals in research and development along with final goods departments, respectively. Also, $P_{\mathrm{x_i}}$and $P_{\mathrm{x_i}}$ are the price of domestic and foreign intermediate inputs. Since intermediate goods are converted into capital, capital price is also considered one unit and interest rate (r) is determined in a perfect financial market. It is also assumed that markets Y and H are competitive for Y production firms. Two criteria exist for intermediate goods: first, it is assumed that inventors are free to enter the business and, second, each intermediate good is produced by a monopoly on the sale. Therefore, the problem can be presented as follows for a final producer:

$$Max\ \pi = Y\{H_y\,, x_i, x_{i^*}^*\} - W_{\mathrm{H_y}} H_y - \int_0^N P_{xi} x_i\, di - \int_0^{N^*} P_{x_{i^*}^*} x_i^*\, di^{\,*} \tag{3}$$

By adopting the required first-order conditions for the above maximization problem, we have:

$$W_{\mathrm{H_y}} = \mathrm{\alpha} \mathrm{Y}/H_y \qquad (4)$$

$$x_{\mathrm{i}} = H_y \, [\mathrm{A}\beta/P_{\mathrm{x_i}}]^{\frac{1}{\mathrm{\alpha}}} \;\; , \;\; \text{i.e.} \quad P_{\mathrm{x_i}} = \mathrm{A}\beta H_y{}^{\alpha} \mathrm{x}^{-\alpha} \qquad (5)$$

$$x^{*}_{i^*} = H_y \, [\mathrm{A}\beta/P_{\mathrm{x}^{*}_{i^*}}]^{\frac{1}{\mathrm{\alpha}}} \;\; , \;\; \text{i.e.} \quad P_{x^*} = \mathrm{A}\beta H_y{}^{\alpha} x^{*\,-\alpha} \qquad (6)$$

According to the above equations, it is clear that all the intermediate goods are employed for the production of final goods; therefore, the same demand function is shared. Producers in intermediate input department use price $P_x$ to maximize current profit at any given time.

$$V(t) = \int_t^{\infty} (P_{\mathrm{x}} \,.\, \mathrm{x} - 1 \,.\, \mathrm{x}) \; \mathrm{e}^{-\bar{\mathrm{r}}(\mathrm{s}\,,\mathrm{t})(\mathrm{s}-\mathrm{t})} ds$$

X is total intermediate inputs which are produced by demand function at any time and $\bar{\mathrm{r}}(\mathrm{s}\,,\mathrm{t}) = [1/s - t] \int_t^{\infty} r(v) dv$ indicates average interest rate between times t and s. Therefore, by assuming a constant value for interest rate, the problem of intermediate firms for selecting a price which could maximize profit is given as follows:

$$\max_{P_{\mathrm{x}}} \pi_m = P_{\mathrm{x}} \,.\, (\mathrm{x} - 1) \,.\, \mathrm{x} \qquad (7)$$

The solution for price of monopoly on the sale is presented below:

$$P_{\mathrm{xi}} = P_{\mathrm{x}} = 1/\beta \qquad (8)$$

A similar method for obtaining the price of foreign intermediate inputs is:

$$P_{\mathrm{x}^{*}_{i^*}} = P_{\mathrm{x}^*}$$

Since domestic economy could be completely combined with global economy, degree of economy openness is used so that, to obtain every X unit from a foreign intermediary, $\mathrm{x} \, e^{\mathrm{D}}$ units should be sent. Therefore, optimum price for a foreign monopoly can be obtained.

$$P_{\mathrm{x}^{*}_{i^*}} = P_{\mathrm{x}^*} = e^D/\beta \qquad (9)$$

By inserting Equations 8 and 9 in Equations 5 and 6, balances value of $\mathrm{x_i}$ and $\mathrm{x_i^*}$ are obtained.

$$x_{\mathrm{i}} = \bar{\mathrm{x}} = \mathrm{A}^{1/\mathrm{\alpha}} \beta^{2/\mathrm{\alpha}} H_y \qquad (10)$$

$$x_i^* = \bar{x}^* = \mathrm{A}^{1/\mathrm{\alpha}} \beta^{2/\mathrm{\alpha}} H_y e^{-D/\mathrm{\alpha}} \qquad (11)$$

Using Equations 1, 10, and 11, balance level of the product is determined as:

$$Y = AH_y{}^{\alpha} \left( N\bar{x}^{\beta} + N^{*} \bar{x}^{*\beta} \right) = \mathrm{A}^{1/\mathrm{\alpha}} H_y \, \beta^{2\beta/\mathrm{\alpha}} \left( \mathrm{N} + N^{*} e^{-D\beta/\mathrm{\alpha}} \right) =$$

$$A^{1/\alpha} H_y\, \beta^{2\beta/\alpha}[N + F(D)N^*] \tag{12}$$

In this case, $F(D) = e^{-D\beta/\alpha}$ , $F(0) = 1$, $F(\infty) = 0$, and $\partial F/\partial D < 0$ and $P_N$ is the patent price of the intermediate product. By guaranteeing free entry into the intermediate department, the reduced value of profit would be equal to the patent price.

$$P_N = V(t) = \int_t^{\infty} \pi_m(s)\ e^{-\bar{r}(s,t)(s-t)} ds \tag{13}$$

Assuming a constant value for interest rate, a specific solution can be obtained owing to the constant value for $P_N$. In this case, the following equation is obtained:

$$P_N = V(t) = \frac{1}{r}\pi_m(t) = \frac{1}{r}(P_x - 1)\bar{x} = \frac{1}{r}(\frac{1}{\beta} - 1)\bar{x} = \frac{1}{r}(\frac{\alpha}{\beta})\bar{x} \tag{14}$$

In the research and development department, total income of research and development activities is as follows:

$$TR = P_N N^{\bullet} = P_N \delta H_N [N + G(D\,, H)N^*]$$

And total costs are as follows:

$$TC = W_{H_N}.H_N$$

Therefore, free entry into research and development department is guaranteed and the payment for human capitals in the research and development department would be:

$$W_{H_N} = \delta P_N [N + G(D\,, H)N^*] \tag{15}$$

Below, Romer assumes that human capital moves between departments. Furthermore, by determining the balance condition and allocating human capital for departments of final production and research and development, Romer states that payments for human capital must be equal in all the departments:

$$W_{H_N} = W_{H_y} \tag{16}$$

Considering Equations 4, 12, 14, and 15, Equation 16 can be rewritten as follows:

$$\alpha\, A^{1/\alpha}\, \beta^{2\beta/\alpha}[N + F(D\,)N^*] = \delta(\frac{\alpha}{r\beta}\bar{x})\ [N + G(D\,, H)N^*]$$

By inserting Equation 10 in $\bar{x}$ in the above equation, the following equation is obtained:

$$H_y \frac{\delta}{r}[N + G(D\,, H)N^*] = \frac{1}{\beta}[N + F(D\,)N^*]$$

Consequently, the above equation can be simplified as Equation 17.

$$H_y = \frac{r[N+F(D\,)N^*]}{\delta\beta[N+G(D\,,H)N^*]} \tag{17}$$

Considering $H_y$, for calculation simplicity, it is assumed that:

$$N^{world} = N + N^* \ , \ \frac{N^*}{N} = u \tag{18}$$

If $u \geq 0$, then there is technology gap between foreign and domestic countries.

$$N = \frac{1}{1+u} N^{world}, N^* = \frac{u}{1+u} N^{world} \tag{19}$$

By inserting Equation 19 in Equation 17, the following relation is obtained:

$$H_{\mathrm{y}} = \frac{r[1+u\, F(D\ )]}{\delta\beta[1+u\, G(D\ ,H)]} \tag{20}$$

Since $H_{\mathrm{N}} = \mathrm{H} - H_{\mathrm{y}}$, Equations 2 and 19 can be used to calculate technology growth rate:

$$g_N = \frac{N^{\bullet}}{N} = \delta H_{\mathrm{N}}[1 + u\, G(D\ , H)] = \delta(H - H_{\mathrm{y}})[1 + u\, G(D\ , H)]$$

By inserting Equation 18 in Equation 12, the following relation is obtained:

$$Y = \ A^{1/\alpha}\, H_{\mathrm{y}} \beta^{2\beta/\alpha}[1 + u\, F(D\ )]N \tag{21}$$

If r is constant, Equation 20 indicates that $H_y$ is also constant; also, $\bar{x}$ is constant according to Equation 10. In this economy, using capital and product, total production grows at an equal rate N. Growth rate $g$ for achieving a static balance growth path for all the variables can be written as:

$$g = g_y = g_C = g_N = \delta H_{\mathrm{N}}[1 + u\, G(D\ , H)] = \delta(H - H_{\mathrm{y}})[1 + u\, G(D\ , H)] \tag{22}$$

Equation 22 shows a positive correlation between growth rate with economic stability g, human capital in research and development $H_N$, and adsorption capacity $G(D, H)$ so that, with increasing human capital in research and development department and improving domestic adsorption capability, growth rate with economic stability is increased. If $H_{\mathrm{N}} = 0$, there is no long-term growth; if $H_{\mathrm{N}}$ is positive and less than H, then g would be positive.

Therefore, stable growth rate would be equal to:

$$g = \frac{\sigma H[1+uG(D,H)-(\rho/\beta)[1+\mathrm{u\ F(D)}]}{1+(\sigma/\beta)[1+\mathrm{u\ F(D)}]} \tag{23}$$

Below, in order to study externalities in the knowledge production function, spatial econometric is used so as to obtain intra- and inter-regional externalities. According to the studies by LeSage and Pace (2009), when data samples have a spatial component, two cases would occur: 1) spatial dependence between observations, and 2) spatial heterogeneity (spatial structure).

Conventional econometric analysis ignores these two issues to a great extent, which could be due to the violation of Gauss-Markov's assumptions used in regression models. Therefore, in order to apply this method, its concepts should be understood. Below, a brief description of spatial heterogeneity and dependence and the way of determining location and spatial lags is presented.

## Spatial dependence

Spatial dependence in a set of sample data means that observations in location i depend on other observations in location j. In other words:

$$Y_i = f(Y_j), \qquad i = 1,2,\dots,n \qquad i \neq j \tag{24}$$

This dependence may exist among different observations and disturbing components and must correspond with fundamental theorems of regional science; i.e. closer observations must reflect a higher degree of spatial dependence than the ones which are distant from each other. In other words, spatial dependence and its effects on observations must decrease with increasing distance between observations.

## Spatial heterogeneity

The term spatial heterogeneity refers to deviation in relations between observations at the level of geographical locations. In most cases, different relations are expected for each point in the space. In other words, linear relation is expressed as follows:

$$Y_i = X_i\beta_i + \varepsilon_i \tag{25}$$

where i, $X_i$, $Y_i$, and $\varepsilon_i$ indicate the obtained observations at points i=1,2,3,…,n in the space, $X_i$ shows n×k vector of descriptive variables along with its related $\beta_i$ parameter set, $Y_i$ is dependent variable in observation or location i, and $\varepsilon_i$ is random error in the above relation. A more complex presentation of this concept is as follows:

$$Y_i = f(X_i\beta_i + \varepsilon_i) \tag{26}$$

Considering Equation 15, it is not expected to estimate a set of n parameters from vector $\beta_i$ considering one sample of observations and unique estimation for each point in the space. Generally, spatial heterogeneity also violates the Gauss-Markov's assumption which suggests only one definite linear relationship with constant variance between sample observations. Therefore, after rejecting the null hypothesis, which states lack of any spatial auto-correlation among disturbing components, spatial error model (SEM), simultaneous auto-regression-regression (SAR) model, general spatial model, or spatial Durbin model can be utilized.

### *Simultaneous auto-regression-regression model*

This model explains y variations as a linear combination of neighboring countries like auto-regressive time series and emphasizes on what occurs in these countries, because knowledge production in every country can be affected by variations in knowledge production and spillovers of neighboring countries. In this regard, method of maximum likelihood can be used to estimate parameters of this model. The above mentioned model is as follows:

$$y_i = \rho \sum_{j=1}^{n} W_{ij} y_j + \sum_{k=1}^{k} \beta_k x_{ki} + \varepsilon_i = \rho W y + X\beta + \varepsilon_i \qquad (27)$$

$$\varepsilon_i \sim N(0, \sigma^2 I_n)$$

*Spatial error model*

In spatial econometric analysis, a model is spatial error model, in which knowledge production is influenced by shock creation in neighboring countries. This model can be presented as:

$$y_i = \sum_{k=1}^{k} \beta_k x_{ki} + \varepsilon_i = X\beta + u_i \qquad (28)$$

$$u_i = \lambda W u_i + \varepsilon_i\ , \qquad \varepsilon_i \sim N(0, \sigma^2 I_n)$$

*Spatial Durbin model*

This model which has the spatial coefficient of dependent variable and descriptive is written as follows:

$$y_i = \rho W y + X\beta + W X\theta + \varepsilon_i \qquad (29)$$

$$\varepsilon_i \sim N(0, \sigma^2 I_n)$$

It must be mentioned that spatial Durbin model is preferred to simultaneous spatial regression-auto-regression and spatial error models, because when $\theta = 0$, SDM is converted into simultaneous spatial regression-auto-regression model, and when $\theta = -\beta\rho$, this model is changed to spatial Durbin model. In addition to simultaneous spatial regression-auto-regression model, in spatial Durbin model, direct effects can be also distinguished from indirect ones. It is worth mentioning that spatial Durbin model is less biased than simultaneous spatial regression-auto-regression model; also, spatial error model results in the elimination of spatial spillovers.

Technology patents resulted from spatial knowledge spillovers from neighboring regions are examples of positive externalities or positive spillovers. A large part of knowledge is implicit and its transfer requires cooperation and common activities. On the other hand, there is explicit knowledge, since conducting ideas to technological patents ensures the existence of people who have relationship with inventors' experience. This knowledge existence increases and is often transferred as a result of discovering new ideas in a region. Knowledge of a particular region and its neighboring regions is a good general commodity, which provokes spatial explanation for knowledge. Spatial regression models can be used to determine spatial extent of spillovers through investigating indirect effects using expanded series $I_n + \rho W + \rho^2 W^2 + \cdots$. Generally, in order to obtain direct effects, first, effect of increasing descriptive variable in country i on dependent variable in country i is calculated (i.e. own-partial derivative is equal to $\frac{\partial y_i}{\partial x_i}$) and since i=1,2,3,…,n, all the effects in the entire region is averaged. To calculate indirect accumulative effect, first, effect of increasing descriptive variable in country j on dependent variable in country i is calculated (i.e. cross-partial derivative is equal to $\frac{\partial y_i}{\partial x_j}$, j ≠ i). Finally, average of these effects in the entire region shows effect of spillovers resulted from increasing the descriptive variable in one country on the dependent variable in all of the countries in the region (excluding the country itself). Overall effect of increasing descriptive variable on all the investigated regions is equal to the sum of direct and indirect effects. Accordingly, the significance of direct and indirect effects of each of the descriptive variables on the dependent variable can be obtained (LeSage and Pace 2009). It is worth mentioning that all the three obtained effects in all countries, time periods, and regions are averaged. Accordingly, the model estimation will be performed in the next section.

## Model estimation

First, the estimated model is introduced based on the theoretical basis and research literature. Then, Moran, Wald, likelihood ratio, and Lagrange multiplier tests are used to determine spatial auto-correlation in the disturbing components. In the case of choosing spatial econometric analysis and confirming spatial correlation between the neighboring countries, the above mentioned models in spatial econometric analysis are used in MATLAB software environment.

For the estimation, a knowledge product function was presented based on Romer's model and research literature as follows:

$$P_{it} = f(HDI_{it}, R\&D_{it}, (G/GDP)_{it}, M_{ijt})$$

where $P_{it}$, $HDI_{it}$, $(G/GDP)_{it}$ , and $M_{ijt}$ indicate patent right, human development index, research and development expenditure, government size, and import of intermediate and final products of destination countries (j) from spillover source countries (i). Since spillover effects were diminished with the increase in distance of countries, therefore, the countries with less geographical distance in Europe were selected. The selected region included Austria, Spain, Slovenia, England, Italy, Ireland, Germany, Portugal, Sweden, France, Finland, Luxembourg, Malt, Norway, and Greece. The following table shows the results for Moran, Wald, likelihood ratio, and Lagrange multiplier tests used for rejecting the null hypothesis suggesting lack of spatial auto-correlation:

Table 1 Moran, Wald, and likelihood ratio tests

| Statistic | Moran I-statistic | Lratios | Walds |
|---|---|---|---|
| Value | 3.547 | 20.849 | 290.766 |
| Probability | 0.005 | 0.000 | 0.000 |

According to the results shown in table 1, statistic of Moran test which was greater than 1.96 and also statistics of Wald and likelihood ratio tests which were greater than 6.635 rejected the null hypothesis suggesting lack of spatial auto-correlation among the disturbing components.

Table 2 Lagrange multiplier test

| **Statistic** | **lmerror** | **Lmerror _ robust** | **lmlag** | **Lmlag _ robust** |
|---|---|---|---|---|
| Value | 13.303 | 9.221 | 5.657 | 1.486 |
| Probability | 0.000 | 0.002 | 0.017 | 0.222 |

According to table 2, statistics for lmerror and Lmerror_robust tests were greater than 6.635 and statistics for lmlag and Lmlag_robust tests were less than 6.635; therefore, SEM had to be utilized. Based on the studies by LeSage and Pace (2009), SEM eliminated the effects of spatial spillover and since the logarithm of likelihood ratio test for SDM was equal to -216.704 and that of SEM was -349.954, SEM was rejected against SDM at 99%. Therefore, SDM was used for the estimation process, the results of which are presented below.

Table 3 Coefficients of variables

| **Variable** | **Coefficient** | **Asymptot t-stat** | **z-probability** |
|---|---|---|---|
| Constant | -37.532 | -6.979 | 0.000 |
| Ln(HDI) | 1.166 | 10.078 | 0.000 |
| Ln(R&D) | 1.301 | 3.100 | 0.001 |
| Ln(G/GDP) | 0.441 | 1.443 | 0.148 |
| Ln(Mij) | -0.578 | -2.027 | 0.042 |
| W*ln(HDI) | 0.846 | 3.072 | 0.002 |
| W* Ln(R&D) | 1.434 | 2.426 | 0.015 |
| W* Ln(G/GDP) | -5.223 | -7.851 | 0.000 |
| W* Ln(Mij) | 4.694 | 6.798 | 0.000 |
| ρ | 0.133 | 1.649 | 0.098 |
| $R^2$ | 0.841 | $\bar{R}^2$ | 0.836 |
| log-likelihood = -216.70413 | | | |

According to Table 3, positive coefficient of endogenous variable ρ indicates that being close to the countries with high knowledge and technology production potential had a positive effect on knowledge and technology production in the region. Human capital, research and development expenditure, and their spatial lags had a significantly positive effect on knowledge production. Effect of government size on registered patents was positive and non-significant, while effect of spatial lags was significantly negative. Industrial imports had a significantly negative effect on knowledge production, while effect of its spatial lags was significantly positive. It must be noted that $WX_i$ variables were called spatial lag of descriptive variables. Using SDM, direct effect of spillover and overall effect can be separated from each other, the result of which is shown in Table 4.

Table 4 Separating indirect effects from direct and overall effects

| Effects | Variable | coefficient | Asymptot t-stat | z-probability |
|---|---|---|---|---|
| Direct | Ln(HDI) | 1.196 | 10.033 | 0.000 |
|  | Ln(R&D) | 1.340 | 3.222 | 0.001 |
|  | Ln(G/GDP) | 0.289 | 0.966 | 0.334 |
|  | Ln(Mij) | -0.442 | -1.561 | 0.119 |
| Indirect | Ln(HDI) | 1.140 | 3.340 | 0.000 |
|  | Ln(R&D) | 1.812 | 2.762 | 0.006 |
|  | Ln(G/GDP) | -5.827 | -7.008 | 0.000 |
|  | Ln(Mij) | 5.208 | 6.086 | 0.000 |
| Total | Ln(HDI) | 2.336 | 5.664 | 0.000 |
|  | Ln(R&D) | 3.153 | 4.348 | 0.000 |
|  | Ln(G/GDP) | -5.538 | -5.899 | 0.000 |
|  | Ln(Mij) | 4.766 | 4.808 | 0.000 |

Maximum sensitivity of knowledge production regarding direct effects was related to research and development expenditure and human capital, respectively. Regarding indirect and overall effects, maximum sensitivity of registered patents was related to government size and knowledge-bearing industrial imports, while minimum sensitivity was related to human capital and research and development expenditure. It must be mentioned that direct effect indicates partial elasticity of exclusive patent right relative to dependent variables in each country and implies the existence of intra-state overspills. In contrast, indirect effect indicates effects of accumulative spillovers in the studied region and shows partial elasticity of exclusive patent right in a country relative to the change of the variables in other countries, which implies the existence of inter-state spillovers in the studied region.

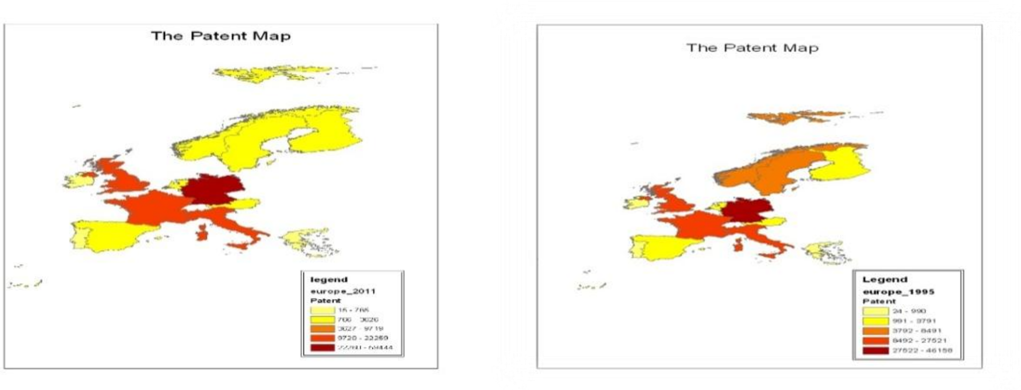
Difference between estimated coefficient for human capital variable, research and development expenditure, knowledge-bearing imports, and government size in SDM in direct effects was 0.0296, 0.0396, -0.152, and 0.1366, respectively, which indicated feedback effects. These effects were created as a result of effectiveness average caused by changing descriptive variable in the country on its own knowledge production, transferring effects to neighboring regions, and its return to the country. This positive accumulative difference was obtained owing to larger estimation of direct effects than that of studied coefficients.

Maximum positive feedback effect was related to knowledge-bearing imports and minimum effect was about human capital and research and development expenditure. Difference between the estimation coefficient of variable lag including human capital, research and development expenditure, and knowledge-bearing imports in SDM for indirect effects was 0.2916, 0.3775, -11.0511, and 0.5135, respectively. These feedback effects indicated the average influence of knowledge production in each country due to changes in the descriptive variables of the neighboring countries and return of the effects to the neighbors themselves.

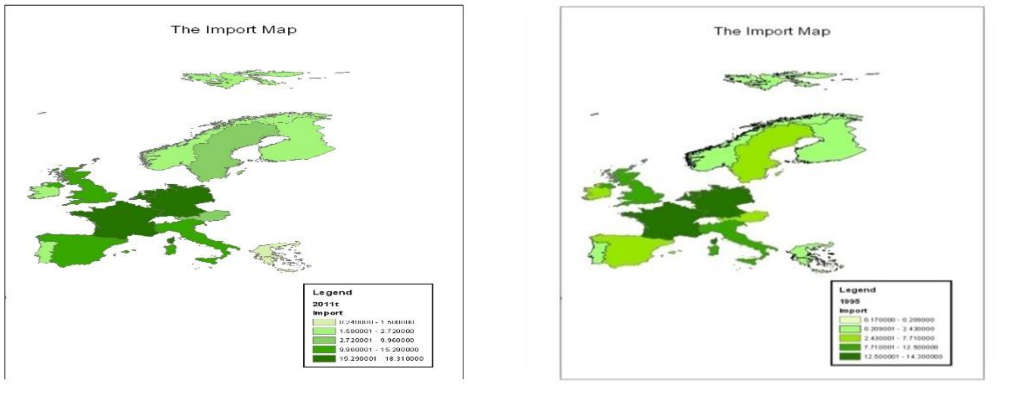
### *Cartographic analysis of patent and imports*

In this section, the aerial maps for 1995 and 2011 are compared by ArcGIS software. These maps show the geographical distribution of patents and imports among countries. According to map 1, the maximum number of patents in 1995 belonged to Germany, England, France, and Italy, respectively; Sweden and Norway were placed in the third order, while other countries were in the primary order. However, in 2011, patent contribution of 4 G-7 member countries increased, while contribution of some countries decreased. Furthermore, according to map 2, the maximum number of knowledge-bearing imports in 2011 belonged to Germany, France, England, and Italy. In 2011, not only these 4 countries owned maximum imports, but also countries such as Spain, Sweden, and Ireland increased their importing share. Also, share of other countries in the region was improved.

These results demonstrated that, within this 17-year time period, the share of some countries in patent and import changed; however, G-7 member countries maintained their ranking among other countries in the region. Numbers for imports were in 1:1000000 scale.



Map 1 Comparing geographical distribution of patent registration in the first region in 1995 and 2011



Map 2 Comparing geographical distribution of imports in the first region in 1995 and 2011

## Conclusion

This study was conducted with the aim of investigating technology spillovers across a number of European countries during 1995-2011. MATLAB software was applied for estimation using spatial econometric analysis. Accordingly, positive effect of human development index and research and development expenditure on patent or knowledge product indicated that knowledge inputs provided a basis for knowledge growth in this region. Furthermore, results demonstrated the dominance of private sector on public sector in terms of knowledge production. In addition, in SDM, knowledge-bearing imports by themselves could not have a positive effect in a country. By including effect of its spatial lag (i.e. influence by neighbors), knowledge product was increased. In addition, average influence of knowledge production in every country resulted from change in human development index in the country itself (i.e. direct and positive effect) and the average feedback effect of this variable was positive. Indirect effect of this variable on knowledge production was also significantly positive, which indicated that positive influencing average of knowledge production in every country resulted from change in human development index in the neighboring countries. In other words, inter-state spillovers of human development index had a positive effect on patent in every country. Also, feedback effect of this change was positive. Finally, since both direct and indirect effects were positive, a significantly positive overall effect was resulted from change in human development index in the region. Furthermore, accumulative direct and indirect effects resulted from change in research and development expenditure on knowledge production in every country and its neighboring countries confirmed the influence of intra-state and international spillovers of research and development expenditure on knowledge production. Also, positive feedback effects resulted from change in research and development expenditure in direct and indirect effects indicated a relationship between research and development department and investments of different countries in this department. Dominance of negative indirect effect of government size on positive and non-significant direct effect in this region admitted that government size in the region did not have a positive effect on knowledge products. It even produced negative feedback effects for the direct and indirect effects. On the other hand, dominance of indirect effect of investment imports on direct effect along with positive feedback effects indicated the influence of patent in all the countries from change of imports in their own and neighboring countries. In other words, every country cannot improve its knowledge self-sufficiently solely through capital imports; however, contribution of other neighbors leads to increased knowledge production. Finally, a significantly positive overall effect was produced and therefore imports made access to hidden knowledge in products and created new technology.

## References

A-Bernard, Corinne and LeSage, James P. (2011). Quantifying Knowledge Apillovers Using Spatial Econometric Models. *Journal of Regional Science* . Vol. 51, NO 3, pp.471-496.

Anselin, Luc, Varga, Attila and Acs, Zoltan. (1997). Local Geographic Spillovers between University Research and High Technology Innovations. *Journal of Urban Economics*, Vol. 42, pp. 422- 448.

Autant-Bernard, Corinne and LeSage, James P.(2011). Quatifying Knoledge Spillovers Using Spatial Econometric Models.*Journal of Regional Science*, Vol. 51, No. 3, pp. 471–496.

Driffield, Nigel and Love, James H.(2003). Foreign Direct Investment, Technology Sourcing and Reverse Spillovers. *The Manchester School*, Vol. 71, No. 6, pp. 659–672.

Fischer, Manfred M. and Varga, Attila. (2003). Spatial Knowledge Spillovers and University Research: Evidence from Austria. *Journal of Regional Science*, Vol. 37, pp.303–322.

LeSage, James and Pace, R. Kelley. (2009). Introduction to Spatial Econometrics. pp. 16- 24.

LeSage, James P. (1999). The Theory and Practice of Spatial Econometrics. pp. 1-20.

Mingyong, Lai, Shuijun, Peng and Qun, Bao. (2006). Technology Spillovers, Absorptive Capacity and Economic Growth. *Journal of China Economic Review*, Vol. 17, pp. 300– 320.

Moreno, Rosina, Paci, Raffaele and Usai, Stefano. (2003). Spatial Spillovers and Innovation Activity in European Regions. *Working Paper*, pp. 1- 37.

Paci, Raffaele and Usai, Stefano. (1999). Externalities, Knowledge Spillovers and The Spatial Distribution of Innovation. *GeoJournal*, Vol. 49, pp. 381–390.

Romer, Paul M. (1990). Endogenous Technological Change. *Journal of Political Economy*, Vol. 98, No. 5, pp. 71-102.