R&D Investments in Slovenia

Mićo MRKAIĆ – Rado PEZDIR***

Abstract

The study analyzes the potential impact of implementation of the Lisbon strategy on Slovenian economic performance. The focus of our work is the recommendation of the strategy that the EU members should invest three per cent of their GDP in research and development (R&D). We analyze this recommendation using comparative descriptive analysis and a simulation of research output with neural networks. On the example of Slovenia we show that Lisbon targets, especially the goal of investing 3 per cent of GDP in R&D, are not necessarily a part of an efficient economic policy. There is no necessary connection between increases in R&D spending and economic efficiency. Investments in R&D are strongly related to interactions between the research sector and businesses and depend on the structure of both sectors. Decisions about investing in applied R&D should be left to market players while economic policy makers should do their best to support R&D activities through structural reforms. This policy prescription applies primarily for transition countries.

Keywords: *research and development, economic policy, transition, science-business relations*

JEL Classifications: C15, C45, O15, O32, P36

Introduction

We asses the potential impact of implementation of the Lisbon strategy on Slovenian real GDP growth. We focus on the core recommendation of the strategy that the EU members should invest three per cent of their GDPs (including public and private investments) in research and development (R&D). It is believed

* Mićo MRKAIĆ, International Monetary Fund, 700 19th Street, N.W., 20431 Washington, DC, USA; e-mail: mico.MMrkaic@imf.org

** Rado PEZDIR, University of Maribor, Faculty of Organizational Sciences, Kidričeva 55/a, 4000 Kranj, Slovenia; e-mail: rado.pezdir@fov.uni-mb.si

that public investment in R&D in the amount of one per cent of GDP and private investment in the amount of two per cent of GDP should improve the transfer of knowledge from academia to business sector and accelerate economic growth. While the recommendation and its goals seem plausible, they are based on several assumptions which are not necessarily fulfilled in all member states. We venture to analyze these assumptions by asking the following questions. First, why would higher per centage of investment in R&D *ceteris paribus* improve its quality and accelerated economic growth? Second, what is the relation between investment in R&D and the structure of the industry-science relations in EU countries? Third, does public investment in R&D in the amount of one per cent of GDP accelerate economic growth or does it only increase budget deficits?

The relationship between investment in R&D and economic performance is complex. It is difficult to reduce it a relationship between few macroeconomic aggregates, as can be shown using the following example. Ireland has had high real GDP growth rates for, but it has not invested large fractions of GDP into R&D.[1] Finland has also experienced high real GDP growth rates, but it has invested heavily in R&D.[2] It is well known that both countries have the reputation of being economic success stories. This example motivates a closer examination of the issue of efficiency of investments in R&D which is ignored in the Lisbon agenda recommendations.

To understand the effects of changes in R&D investment on economic growth it is necessary to study two issues: (i) structural characteristics of R&D process, specifically the labor and capital markets in academia, and (ii) the nature and quality of the interactions between academia and industry. If scientific research is funded only by the government and does not focuses on applied research, then the transfer of knowledge from the R&D sector to industry is likely lacking. Investment in such scientific activity is not necessarily socially efficient.

Another factor which affects the dissemination of research results is the depth of capital markets. If financial markets are not well developed, increased public investment in R&D (through special seed banks or para-state funds) and the use of the tax system to stimulate private investment in R&D, are likely suboptimal strategies to increase total investment in R&D. Under the described circumstances increased public investment in R&D could crowd out private investment in R&D (venture capital funds, private seed banks, business angels etc.). Crowding out could present problems for those new member countries whose financial markets are underdeveloped.

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[1] In 2003 Ireland invested 1.12 per cent of GDP in R&D.

[2] In 2003 Finland invested 3.51 per cent of GDP in R&D.

Because economic environments in the EU countries states vary greatly, an application of the Lisbon strategy recommendations which does not take into account the microeconomic fundamentals of country-specific interactions between academia and industry, can have mixed results. This is the opposite of what sound economic policy should be. The Lisbon strategy does not address the issues of efficiency of R&D expenditure, science-business relations, the structure and depth of financial markets, and other important issues which affect the production of knowledge and its transfer from academia to industry. The strategy is primarily concerned with the amount of resources that should be invested in R&D, but it does not address the microeconomic conditions for a successful application of economic policies that it prescribes. It follows that caution should be exercised when applying the recommendations of the Lisbon agenda. We analyze in depth the case of Slovenia and demonstrate that applying the Lisbon strategy without implementing structural reforms of the Slovenian research sector will not increase the growth of real GDP. We believe that the results of our analysis are general enough to be applied to other EU members. In addition to the analysis of the effects of the Lisbon strategy we describe some necessary measures that must be implemented in order to increase the productivity of R&D activities and improve the transfer of knowledge from R&D to industry.

To simulate the effects of implementation of the Lisbon strategy we use neural networks, since they allow for great flexibility in functional approximation.[3] We analyze the trajectory of gross investments in research and development (GERD) and assess the effect of changes in selected structural parameters on GERD. The use of neural networks is justified, since we do not use a structural econometric model to explain R&D investment activity, and since available time series are too short for a rigorous econometric analysis.

This paper is organized as follows. In the Second section we describe the institutional organization of R&D sector in Slovenia and the interactions between the sector and the economy. In the Third section we perform simulations of key macroeconomic aggregates under the Lisbon policy recommendations by using neural networks. The Fourth section concludes.

1. Interactions between Research and Industry Sectors

To understand the importance of the microeconomic structure of the relationship between R&D sector and industry we describe the key institutional features of the relationship and their summary statistics.

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[3] We use feed forward neural networks.

1.1. Some Features of Slovenian R&D Sector

In order to investigate science-business relations in Slovenia we conducted a survey of Slovenian research institutions in 2004 (Mrkaić and Pezdir, 2004). To establish compatibility with studies from other countries the survey is based on the OECD classification of the level of formality of science-business relations (OECD, 2000). We queried 44 science and technology institutes and received 19 responses. The respondents reported their relations with industry by ranking different forms of cooperation on a scale from 1 to 5. The results are shown in Table 1.

T a b l e 1

Forms of Cooperation between Science and Business in Slovenia

Formality of cooperation	Form of cooperation	Slovenian rank	Average value
1 (most formal)	Joint research laboratories	6	2.26
2	Establishment of spin-off enterprises	8	1.83
3	Licensing and patenting of joint R&D achievements	7	2.00
4	Contracts for joint R&D	2	3.21
5	Mobility of employed between science and business	5	2.50
6	Joint publications in scientific literature	4	3.00
7	Joint conferences and seminars	3	3.11
8 (least formal)	Informal contacts	1	3.58

Source: Mrkaić and Pezdir, 2004.

The most common science-business relations in Slovenia are the least formal ones. The least common relations are the most formal – the establishment of joint research laboratories. The general tendency of cooperation between science and industry in Slovenia tends to be informal. We conjecture that the transfer of applicable knowledge from research institutions to industry in Slovenia tends to be weak.

The comparative position of the Slovenian R&D sector is described in Table 2. We see that Slovenian R&D sector produces few highly cited scientific publications. The sector is lacking in quality to produce leading research. It is also lacking in the ability to produce high quality applied research. This fact is demonstrated by the low numbers of patent applications at the European and the US Patent Offices. The practical consequence of weak Slovenian science is a low share of high tech exports in Slovenian exports.

Table 2 also shows that in quantitative terms the scientific production in Slovenia is not below the average of the EU-15 countries; however it indicates that the quality of Slovenian research is well below the EU-15 standards. This conclusion is supported by the low number of highly cited scientific publications produced by Slovenian researchers. The table also demonstrates that applied researchers in Slovenia are less productive than their EU-15 counterparts and that low productivity and low quality of their research result in a share of high tech exports which is well below the EU-15 average. All these findings indicate that Slovenian R&D sector could not, ceteris paribus, absorb an increase in investment in R&D without undergoing a significant restructuring. An increase of funds that are available to the R&D sector in Slovenia will not change its structure and increase the sector's efficiency. In order for Slovenian R&D sector to be more competitive, it should reach operational parameters which are more in line with those of the R&D sector in Finland. Finland produces many scientific publications, many of which are highly cited, while Slovenian research output is predominantly limited to the production of low and medium quality publications in basic research.

T a b l e 2

Scientific Output and Share of High Tech Export in Total Export

	Patent applications, European Patent Office (2002)[1]	**Patent applications, US Patent Office (2002)[1]**	**Scientific publications[1] (1995 – 2002)**	**Highly cited scientific publications[1] (1997 – 1999)**	**Share of high tech export (2001)**
Austria	174.8	65.6	871	26	14.6
Belgium	148.1	70.4	929	42	9.0
Denmark	214.8	83.8	1 332	69	14.0
Finland	310.9	158.6	1 309	50	21.1
France	147.2	68.1	712	26	25.6
Germany	301.0	137.2	731	29	15.8
Ireland	89.9	32.4	542	27	40.8
Italy	74.7	30.3	647	18	8.5
Netherlands	278.9	86.6	1 093	55	22.3
Slovenia	**32.8**	**8.4**	**726**	**3**	**4.8**
Sweden	311.5	187.4	1 598	58	14.2
UK	128.7	64.5	1 021	54	26.4
EU-15	158.5	71.4	673	31	19.8

Note: [1] Per million inhabitants.

Source: Indicators for benchmarking national research policies, and <http://epp.eurostat.cec.eu.int>.

It follows that there are three important features of the interaction between the R&D sector and industry in Slovenia. First, these interactions are weak and in most cases less formal. Second, scientific output is dominated by the production of low to medium quality studies in basic research. Third, low patent activity is an indicator of limited transfer of knowledge from the R&D sector to the business sector. The consequence of these institutional features is a low share of high tech exports in total exports; the above described institutional features result in a crowding out effect where innovative applied research and high quality basic research are substituted by low and medium quality research in basic science.

Table 3 provides an explanation for the above described features of Slovenian R&D sector. The distribution of researchers between science and business sector is skewed towards basic science. Only one third of Slovenian researchers are employed in industry. This distribution is significantly different from the distributions of researchers in other EU countries. Differences in the distribution between sectors are even larger if we compare Slovenia to the USA and Japan. The most important reason for the high concentration of researchers in basic science in Slovenia is that the majority of research institutes and all universities are state owned and financed by the government.

T a b l e 3
Distribution of Researchers by Sector in 2001

	FTE Researchers by Sector		
	Business	Basic1[1]	Higher education
Austria	62.6	5.1	31.8
Belgium	54.5	4.0	40.4
Denmark	47.9	20.7	26.3
Finland	56.9	12.3	29.8
France	47.1	15.2	35.8
Germany	59.3	14.4	26.3
Ireland	66.1	8.7	25.2
Netherlands	47.6	14.1	37.2
Slovenia	**33.6**	**32.3**	**30.7**
Sweden	60.6	4.9	34.5
UK	57.9	9.1	31.1
EU-15	49.7	13.4	34.5

Note: [1] Basic: publicly funded basic research institutions.
Source: <http://europa.eu.int>.

The government, as the founder of public research institutes and universities, is obliged to guarantee their financial stability regardless to their (in)efficiency. Financing of program groups in state the public research sector is not based on well defined R&D targets and is not related to the goals of economic policy. Scientific output in the public research sector is also not related to the amount of resources that it receives from the government.

Wages in the public research sector are not related to the marginal productivity of researchers and are paid even if there is no market for the produced scientific output. Such policy does not stimulate researchers to take risks to market the results of their research.[4] Wages are also paid if the quality of research is low. This incentive mechanism is the major cause of the low labor mobility between academia and industry. It also causes the skewed distribution of scientists between the sectors in Table 3.

[4] The problem is exacerbated by the collective bargaining agreements between the science trade unions and the government.

Scientists prefer risk free wages in the public science sector to uncertain wages in business sector.

Another factor hampering efficient collaboration between the research and business communities in Slovenia is rigid economic environment. EBRD reports that in 2000 Slovenia had the largest share of state owned sector in GDP (35 per cent of GDP) among all transition countries. The government in Slovenia plays an unusually large role in the economy. Large subsidies, measured as a share on GDP (Eurostat, 2004), coupled with a political mechanism of allocating financial resources to unproductive state owned research institutions reduce incentives for researchers to produce marketable products.

Foreign direct investment (FDI) in transition countries has served as a channel for enhancing R&D activities and increasing competitive pressures on state owned enterprises. This is especially true about networking industries – fixed and mobile telephone operators, internet providers and electric power producers – which are important centers of R&D activities. The flow of FDI to Slovenia has been much less than to other transition countries and the authorities often covertly discouraged FDI.[5]

Studies of business environment: IMD (2005), WEF (2004), and World Bank (2005) show that Slovenia has a business environment with many administrative barriers, and complicated and lengthy administrative procedures which reduce the ease of doing business. Shallow financial markets, politically motivated government interventions, a large number of markets distorted by state owned incumbents, rigid bureaucracy, heavy tax burden[6] and rigid labor markets (see for example World Bank, 2005, and WEF, 2005) all contributed to the uncompetitive business environment in Slovenia. It must be added that the business environment in Slovenia is uncompetitive in general, not only in the R&D sector.

Slovenian Firms which intend to enter R&D sector face rigid labor markets and heavy competition from the public research sector. The market for researchers is distorted by state owned incumbents who prevent or deter entry of private research institutions.

Barriers to entry for new entrants are substantial, therefore there are few private research institutes in Slovenia. The consequences of these policies are described in what follows.

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[5] Latest withdrawals of major foreign investors such as VEGA, Inbrew and KBC from Slovenia show that the practice of limiting foreign investments is still alive. All three withdrawals occurred under political pressure of nationalist forces which opposed selling companies of "national interest" to foreigners.

[6] Slovenia has a tax system with five tax brackets. The highest marginal tax rate on labor is 42 per cent. Slovenia also has one of the largest shares of government expenditures in GDP (47.3 per cent of GDP in 2005) in the region.

Table 4 shows that the distribution of sources of R&D funding in Slovenia does not differ from the distribution in other EU countries. This finding could be attributed to a political mechanism of allocation of funds in the research sector, and to the unfinished transition in both the research (stable state funding has discouraged research institutions to search for additional funding by offering their research to businesses) and the business sector.

T a b l e 4

Sources of R&D Financing (in per cent) in 2001

	Private	Government	Other	Foreign
Austria	39.0	42.1	0.3	18.6
Belgium	66.2	23.2	3.3	7.3
Denmark	58.0	32.6	3.9	5.3
Finland	70.8	25.5	1.2	2.5
France	52.5	38.7	1.6	7.2
Germany	66.0	31.5	0.4	2.1
Ireland	66.0	22.6	2.6	8.9
Netherlands	50.1	35.9	2.6	11.4
Slovenia	**54.7**	**37.1**	**1.1**	**7.2**
Sweden	71.9	21.0	3.8	3.4
United Kingdom	46.2	30.2	5.7	18.0
EU-15	56.1	34.0	2.2	7.7

Source: <http://europa.eu.int>.

Inefficient transfer of knowledge from research institutions to businesses and low average quality of Slovenian research contributed to slow growth of total factor productivity in Slovenia. Mrkaić (2002) and Jongen (2005) show that the growth rate of total factor productivity in Slovenia has been decreasing since mid 1990s. Landesmann and Stehrer (2002) show that changes in manufacturing during "hardcore transition (1993 – 2000)" in Slovenia have been the smallest among the transition countries. From 1993 to 2000 in Slovenia the share of medium and high tech products in total industrial production rose from 25.3 per cent to 29.6 per cent. Increases were significantly larger in the Czech Republic (from 25.6 per cent to 36.4 per cent), Hungary (from 16.7 per cent to 56.8 per cent) and Slovakia (from 18.1 per cent to 32.9 per cent). Structural anomalies in the Slovene R&D sector and in the interactions between the R&D sector and businesses are reflected in a low share of high tech exports. Only 4.8 per cent of Slovene exports are high tech.

Using the share of high tech exports as a measure of the efficiency of knowledge transfer from academia to industry Slovenia lags behind the majority of the EU member states, and also behind several transition countries. The share of high tech exports as per cent of all exports in Estonia is 14.6 per cent, in Czech Republic 9.2 per cent and in Romania 5.0 per cent.

2. Simulations

It is plausible to claim that increasing investments in R&D *ceteris paribus* would not increase the growth rate of the Slovenian economy. The efficiency of investments in R&D depends on the microeconomic structure of the R&D sector and on the integration of this sector into the national economy. The question that is addressed in this section is: how would increased investment in R&D change the real GDP when all other relevant factors are held constant? We answer this question by simulating the growth of GERD expenditures for several European Union countries.

Scientific activity, flexible factor markets and R&D investment structure are the most important factors of innovation activity. Growth in R&D investments can be efficient only in the environment of intensive interactions between R&D sector and businesses. In the absence of a measure of intensity of interactions between R&D sector and businesses (apart from the descriptive rankings used by OECD) we assume that above listed factors of R&D activity could serve as proxies for the strength of interactions between R&D sector and businesses. This assumption is supported by practical observations. For example: experiences of Finland and Ireland indicate that fast economic growth supported by investment R&D activity also implies market oriented scientific production and the distribution of FTE (full-time equivalent) researchers in favor of the business sector.

In simulations we used data on R&D activity in several EU countries as input variables. We assumed that their innovation activity is more efficient than it is in Slovenia. This assumption has an important implication for our simulations – it helps us understand how an increase of investments in R&D can increase the growth of real GDP.

To perform simulations of the impact of the implementation of increases in R&D investment we use neural networks. The main reason for this choice is lack of sufficient data to apply standard econometric techniques.

The explanatory variables to approximate the GERD trajectory are: business sector R&D investments, the number of researchers per 1000 of active population, the number of patents applications at the EU patent office per million of population, and the number of patents applications per million of population at US patent office.[7]

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[7] One could use additional explanatory variables: the number of new PhDs in science and technology, the share of private sector in financing R&D in education, the share of private sector in financing R&D in state owned sector (institutes), the share of government in financing R&D in business sector, the fraction of researchers in business sector, the share of high tech export in total export etc. However, the observations of these variables are incomplete and cannot be used in the quantitative analysis.

We approximate the GERD trajectory by using the following neural network:[8]

$$y_t = \theta_0 + \theta_0 \frac{1}{1+e^{-(w_{11}x_1+\ldots+w_{17}x_7)}} + \theta_2 \frac{1}{1+e^{-(w_{21}x_8+\ldots+w_{27}x_{14})}} + \ldots + \theta_5 \frac{1}{1+e^{-(w_{51}x_{21}+\ldots+w_{56}x_{27})}} \quad (1)$$

In equation (1) $x_i,\ldots x_n$ are input variables, and $w_{i,j}$ are input weights which are estimated by training the neural network. $\theta_1,\ldots\theta_5$ are estimated parameters, which are also estimated by training the neural network. y_t is the estimated value of output. The parameters are estimated by minimizing the distance between observed and approximated value of GERD using nonlinear optimization techniques.

Table 5 shows that observed and fitted values of GERD are very close, which indicates a good fit of the neural network and shows that the chosen functional form is appropriate. Estimated values of coefficients and weights are reported in tables and appendix.

T a b l e 5

Actual and Estimated Values for Slovenian GERD

	Actual values	**Estimated values**
1997	1.33	1.329999
1998	1.39	1.390000
1999	1.42	1.419997
2000	1.44	1.440002
2001	1.56	1.559999
2002	1.53	1.529998
2003	1.53	1.529999

Source: <http://epp.eurostat.cec.eu.int>.

Using the neural network (1) we simulated four investment scenarios, using different assumptions about the growth of input variables. We used these simulations to forecast the growth of GERD.[9] The important result is that forecasted GERD values do not vary significantly when we vary the values of input variables. The first scenario assumes historical growth rates of input variables observed during the analyzed period. In the other three scenarios we assumed that the growth rate of inputs for Slovenia is 1, 2 and 3 percentage points above the

[8] We used data for Austria, Belgium, Denmark, Finland, Ireland, Germany and Spain. Data for other countries were incomplete. We did not use data on transition countries since we assumed that their R&D activities and science-business interactions reflect the same problems as in Slovenia. For the number of researchers we used data for EU-15 in order to avoid problems with statistical identification.

[9] Forecasts were calculated for a three years horizon. Longer forecasts would not be realistic, given the short time series on input data.

historical growth rates, and that inputs for the EU members grow at historical rates. Annual growth rates used in the simulations are presented in Table 6.

T a b l e 6

Annual Average Growth Rates used for Simulations

	Historical annual average growth rates
Private investment in R&D[1]	4.41
Researchers[2]	1.42
Applications, EU Patent Office[3]	8.73
Applications, US Patent Office[3]	13.93

Note: [1] Per cent of GDP; [2] in 1000 FTE; [3] per million population.

Results of the simulations are summarized in Table 7. The results indicate that despite changes in growth rates of input variables, the GERD trajectory does not vary significantly. This implies that following the Lisbon target and investing 3 per cent of GDP in R&D is not efficient.

T a b l e 7

GERD Simulations

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2004	1.584122	1.584243	1.584365	1.584487
2005	1.587425	1.587647	1.587872	1.588098
2006	1.590795	1.591127	1.591463	1.591804

In the case of for Slovenia, which exhibits modest growth rates of marketable scientific production and low labor mobility of scientists, this conclusion appears justified. Increasing the investment in R&D without significant changes in the structure of the R&D sector and in the interactions between research and businesses seems unproductive.

To illustrate the above finding we analyze R&D investment in Ireland. Their GERD is significantly lower than it is recommended by the Lisbon strategy, it is lower than Slovenian GERD, and has been declining. The same trend can be observed in Irish private R&D investment. At the same time Irish scientific output has been larger than it is in many other EU countries.[10]

These facts are not true exclusively of Ireland. Table 4 shows the share of investments in R&D as a fraction of GDP in selected EU countries. Tables 2 and 4 show an interesting fact: countries with significantly different levels of investment in R&D have approximately equal levels of research output and vice versa. It is thus not rational that the focus of the Lisbon strategy should primarily be the

[10] See for example share of high tech export in total export and patent activity.

volume of investments in R&D and not the structure of research sectors in the EU countries.

Conclusions

The results lead to the following conclusion: the amount of resources invested in R&D is equally (or less) important than the efficiency of the investments. The Lisbon target of allocating a certain per cent of GDP to R&D is not a sufficient condition for increasing economic growth and the efficiency of European economies. Relatively low R&D investments in Ireland are efficient, while only increasing R&D investments in Slovenia and not pursuing necessary structural reforms will not improve the efficiency of R&D and will not increase the quantity of marketable scientific output.

The simulation shows that additional spending on R&D without structural reforms in the economy would only preserve market rigidities and inefficiencies. In Slovenia increased public funding of the research sector (which is almost exclusively state owned) would mean continuation of production of low quality research articles. Such economic policy would keep alive state owned research monopolies by increasing barriers for newborn scientific institutions to enter the market. It would also preserve the rigid market for researchers and barriers to entry of new private research firms.

On the example of Slovenia we have shown that Lisbon targets, especially the goal of investing 3 per cent of GDP in R&D are not a part of an efficient economic policy. There is no necessary connection between increasing R&D spending and economic efficiency. Efficient investments in R&D depend on interactions between the research sector and businesses and on the structure of both sectors. Artificial allocation of investments (as suggested by the Lisbon agenda) has no ground in market economics and could be unproductive. We have proved a limited version of this result by showing that under realistic circumstances the Lisbon recommendation would not perform well in Slovenia. We think that decisions about investing in applied R&D should be left to market players while economic policy makers should do their best to support R&D activities through structural reforms. Privatization, liberalization, increasing competition in academia and industry, reforming public finance, limiting and streamlining bureaucracy and increasing flexibility of factor markets should be given higher priority than artificially increasing investments in R&D. This policy prescription holds primarily for transition countries.

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