INSTYTUT BADAŃ SYSTEMOWYCH
POLSKIEJ AKADEMII NAUK

TECHNIKI INFORMACYJNE TEORIA I ZASTOSOWANIA

Wybrane problemy
Tom 5 (17)

poprzednio

ANALIZA SYSTEMOWA W FINANSACH
I ZARZĄDZANIU

Pod redakcją
Andrzeja MYŚLIŃSKIEGO

Warszawa 2015

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INNOVATION FOR R&D SECTOR DEVELOPMENT

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Abstract. The paper examines whether focusing on innovations might change supporting system of R&D sector in Poland. The proposed supporting system is an extension of the mapping R&D sector proposed earlier by the author. The system uses a network, which is a facility for dynamic programming in task to search for a better solution.

Keywords: innovations, R&D sector, neural networks, dynamic programming, the task of searching for a better solution

1 INTRODUCTION

The sustainable development of the country in the time of globalization requires a systemic approach to the development planning. It becomes more and more important to provide innovative goods and services to the market. Development and commercialization of products, processes and services are recognized as challenges and opportunities for Poland [2,12,13]. European Union Structural Funds 2014-2020 were designed in the way to support innovation development across EU countries as priority matters. We can consider a various scenarios how innovation can lead to economic development what might be the role of R&D support.

In [1] author has presented system approach on supporting Poland R&D sector development. The system is based on three pillars.

The first pillar of the system is a model of R&D sector in Poland based on neural network [3,4]. The second pillar is dynamic programming, which uses a data delivered by first pillar to provide opportunities on analyzing impact of decision-making variables to system outputs. The third pillar is an expert or analyst challenges support system works in terms of values ranges. Three pillars system decision support system for R&D sector in Poland is presented on Fig. 2. For the decision variables system is expected to ensure that the output parameters are the most suitable for development strategy.

In the paper I would like to present system modification to take into consideration innovation aspect which might impact on overall R&D model. It was considered how innovation expenditures might be added to system proposed in the paper [1]. Over last year's innovation is playing important role on economy development then it was interesting for me to ensure R&D model can acquire investments and expenditures allocated for innovation matters. It is important assumptions as supporting system offers executing long-term analysis of the R&D sector development. It will support decision-making processes, enabling to obtain the best results in its development planning decisions.

2 THE PROPOSED SYSTEM SOLUTION

The World Bank [4] highlighted a few important items regarding appropriate utilization of European Union Structural Funds 2014-2020 in Poland where 10 Euro Billion are allocated for innovation and digital economy [14]. The World Bank presents overall spending on R&D sector in Poland as below 3 % of GDP defined by Europe 2020 strategy. R&D sector in Poland is set up internally as of 1.7 % GDP and we are close to achieve that decreased target.

There is three more The World Bank advices as following:

- Poland, as a high income country, is committed to fostering sustainable income growth for the bottom 40 % of its population.
- Innovation is considered a key component for growth in Poland and the country is utilizing Euro10 billion in structural funds from the European Union to stimulate commercially oriented research, particularly in the private sector.
- Utilizing World Bank Group Reimbursable Advisory Services (RAS), policymakers engaged experts from around the globe – including Chile, Israel, and Denmark – to develop strategies and design programs that would best leverage these funds.

I would like to present example on successful implementation of Operations Program Innovative Economy 2007-2014 [8] brought estimated numbers of benefits in Poland:

- 44 000 new jobs created
- 11 155 enterprises supported (10 833 Small Medium Enterprises)
- 890 scientific entities engaged in projects
- 11 300 scientists engaged in projects

- 4 400 new products and services introduced in enterprises
- 1 200 new technologies implemented in enterprises
- 550 enterprises implemented results of R&D studies
- 1 800 new innovative ideas incubated
- 300 start-ups created

Smart Growth Operational Program (SG OP) is designed as successor of Operations Program Innovative Economy will be executed in period of 2014-2020. Objective for Smart Growth Operational Program in Poland is increasing of business and private sectors investments in R&D development [8]. SP OG is successor of Operational Programme Innovative Economy held in period of 2007-2014. SG OP objective is to increase gross domestic expenditure on R&D to GDP from 0,9% in 2012 into 1,7% in 2020. The similiar improvement is expected in terms of increasing business expenditures on on R&D to GDP from 0,29% in 2012 into 0,6-0,8% in 2020.

The list of Smart Growth Operational Program objectives includes the following axes presented on Fig. 1:

- Support for R&D of enterprises and scientific-industrial consortia as of 41.02% (I on Fig. 1)
- Support for innovation in enterprises as of 27,05% (II on Fig. 1)
- Supporting the environment and potential of innovative enterprises as of 12,54% (III on Fig. 1)
- Increasing the potential of research institutions as of 15,94% (IV on Fig. 1)
- Technical assistance as of 3,45% (V on Fig. 1)

R&D sector is built upon institution and people deliver development of knowledge and extending applications for existing technologies. There is various outcomes of sector as of products, processes, technologies and essential innovations.

This is list of key R&D environment components defined by Central Statistical Office of Poland:

- Poland Academy of Sciences
- R&D Units
- Higher education institutions operating in the field of R& D
- Knowledge and technology parks
- Innovative Enterprises

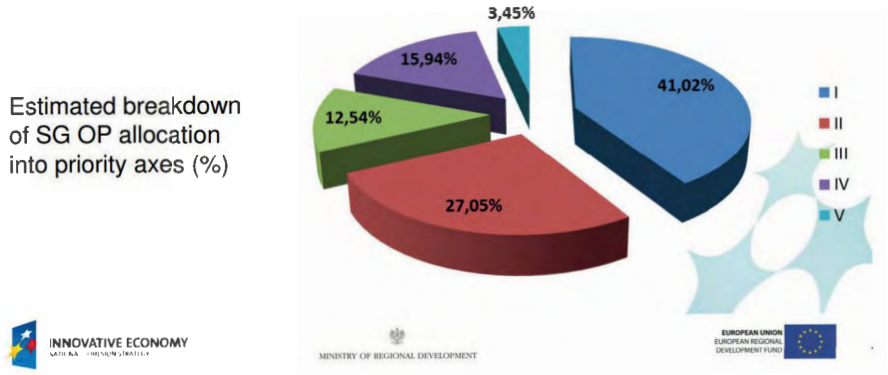

Fig. 1. Łata M. - Estimated breakdown of SG OP allocation into priority axes (%) [8].

The important goal for system supports R&D sector is to predict what will happen in the future if not appropriate action will be taken in certain point of time [2]. Implementation of the development strategy must consider R&D sector advantages, which significantly can change the negative trend or can actively provide risk mitigations. For instance, restriction of people resources who can actively develop national product needs to trigger in the system increasing the productivity of the resources making GDP [5,6].

Since innovation plays key and conducive role on R&D development then it is important to ensure investment on innovations and innovations outcomes will be enclosed in the system. It is crucial we will get appropriate design and link between scientific research objective and goals to proper financial model of the sector. At the end it could help to reverse long-term forecast of Poland GDP presented in OECD report [14].

The proposed system solution is design for long period of time. It support R&D sector with three pillars:

- Model of R&D sector in Poland created as of neural network
- Dynamic programming, which uses a data delivered by first pillar
- Expert or analyst challenges support system data

System details are presented in paper [1] the next section consists short system description.

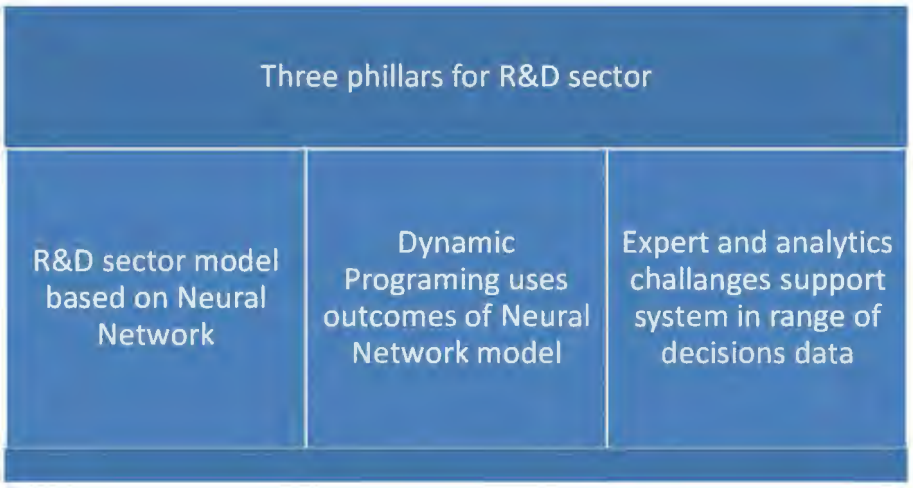

Fig. 2. Chmielewski J. - Three pillars system decision support system for R&D sector in Poland [1].

3 R&D SECTOR MODEL

R&D sector model is a very important element of the proposed decision support system. Without that model it is hard-to-find elements need to be modified in order to achieve the expected goal. There are different approaches to creating a model of R&D sector in Poland. In my opinion, an interesting approach is model of R&D sector in Poland based on neural network next to a mathematical model or a statistical solution [1,3,10].

Data for R&D sector are available on the websites of statistical agencies including the Central Statistical Office (GUS, Poland) and Eurostat as well as in the reports and studies of the sector.

3.1 Neural Network

To build R&D sector model using neural network it is used the application Neuroph Studio developed by Zoran Sevarac and team of Belgrade University, Serbia [11].

The explicit form of the equation of neural network with three hidden layers has the form [1]:

$$a^3 = f^3(W^3 f^2(W^2 f^1(W^1 p + b^1) + b^2) + b^3) \tag{1}$$

Where:

- a^3 - Output of the third layer
- f^w - Activation function of the neuron layer where w=1,2,3
- W^w - Weight matrices layers where w=1,2,3
- p - Input data matrix
- b^w - Matrix of bias layer where w=1,2,3

Output of neural network is input data for dynamic programming system using DP2PNSolver. Neural Network output is in the form of a matrix of weights and transformations functions. Dynamic programming will give expert or system analyst decision-making data then dynamic programming system will evaluate the best solution with the desired data range of decision-making variables.

Dynamic programming problem has been defined as search of the best solution for the decision-making variables introduced by an expert or analyst, examining the impact of input variables for output parameters. Experts or analyst can examine system with ranges of variables which are realistic based on their knowledge and experience. An expert or analyst can simulate behavior of using the preferred development strategy of R&D sector during the examined period of time. One call apply different strategies by observing how the system responds to change the parameters of decision-making variables.

3.2 Dynamic Programming

Dynamic programming problem is defined as the search for the better solutions for output parameters at intervals defined by the input parameters in the range defined by expert or analyst.

Dynamic programming problem is solved using the DP2PNSolver package developed by [7,9], which enables to resolve issues in a dynamic programming. DP2PNSolver utility contains modules on two levels: the first Level contains the entrance to the introduction of the specification for discrete problem DP. The specification of the problem being processed is on Petri net interim (PN) representing the Bellman network (BN). Interim tier problem is standardized to mathematical modeling problem. The optimal solution to the problem is provided by a second layer called the output in the form of a code (Java or Excel sheet).

Dynamic programming task is defined as the search for the better solutions for output parameters at intervals defined by the input of an expert or analyst.

$$a_5^3 = \max_{p_1,p_2,p_3,p_4} f^3(W^3 f^2(W^2 f^1(W^1 p_n + b^1) + b^2) + b^3) \tag{2}$$

Where:

- a^3- Matrix output
- a_1^3 - Investment in fundamental research
- a_2^3 - Investment in R&D sector enclosing innovations
- a_3^3 - Investments in innovative enterprises
- a_4^3 - Investment in science and technology parks
- a_5^3 - Transfer the results to the economy enclosing innovation improvement
- f^n - Activation functions of neurons in each layer neural network where n=1,2,3
- W^n- Weight matrices of neurons in each layer neural network where n=1,2,3
- b^n - Bias in the individual layers of the neural where n=1,2,3
- p_n- Decision-making matrix input where n=1,2,3,4
- p_1 - Expenditures on R&D sector enclosing innovations
- p_2 - Business expenditures on R&D sector
- p_3 - Expenditures on education system
- p_4 - Expenditures for the support system
- p_1, p_2, p_3, p_4 - belong to a range of expert decision-making data

Investmens and expenditures numbers will be delivered as of amounts in PLN polish zloty. We can present R&D decision support model as observation outcomes like what is expected investment to technology parks if we allocate certain amount of investments as business participations in the financial support. I have suggested to focus on transfer of R&D results to the economy enclosing innovation improvement as key success criteria. Transfer of R&D results is amount of PLN polish zloty what business is paying for products or servces delivered by R&D sector.

Explicit picture of neural network [3] allows to make connection between Neural network and dynamic programming. Neural network maps impact go to exit through a system of weights of neurons that are explicit. The weight shall be transferred to the dynamic programming system, so we have a system reproducing the behavior of the R&D sector-development on the input parameters, which will be introduced by an expert or analyst. From this stage dynamic programming system is ready for analysis and presentation of results for the search for a better solution.

3.3 Better Solution Approach

The concept of better solution approach might be a matter of experts discussions who can present different preferences of the R&D sector development. My approach of better solution is the direction the development of the sector R&D, which allows maximizing the transfer of research results to economy and business enclosing innovation gain.

Better solution is based on the following decision-making variables [1]:

- Expenditures on R&D sector enclosing innovations
- Business sector expenditures on R&D sector enclosing innovations
- Expenditures on education system
- Expenditures for the support system

Decision-making variables in range preferred by expert or analyst give data output on resources relocation where transfer of R&D sector research results to economy is set up as goal for maximizing allocation:

- Investment in fundamental research
- Investment in R&D sector enclosing innovations
- Investments in innovative enterprises
- Investment in science and technology parks

I have defined goal for the system to get better results on transferring R&D outcomes to economy what might positively influence on economy

development and increasing of innovations. This approach is driven by assumption search for better results can help to avoid slowdown of GDP growth [2].

Better solutions approach is implemented in dynamic programming system as following steps:

- Transfer the results of research to the economy and business is examined for input data ranges advised by experts .
- Dynamic programming task is performed in four steps separately for any given investment decisions for fundamental research, R&D sector enclosing innovations, innovative enterprises and science and technology parks.
- In each step, only one decision is a test range, the remaining data is fixed. The value of a decision giving the greatest value of transfers in the next step, for the next decision is the value of a constant.
- IThe result is a collection of four decision-making parameters that give the value of the maximum transfer of the results of R&D sector to business and the economy.

This is important observation innovation expenses and investments can be enclosed to proposed model of R&D sector in Poland [1]. It proves model stability where changes of environment might be properly mapped It may be challenge to collect statistical data regarding innovations as for instance it could be not consistent approach how data is presented by statistical offices. Aspect of data availability needs to be carefully considered some of improvement we can get by experts knowledge what highlight importance of experts in three pillars sector model.

Numerical data for proposed decission supported system will be delivered as next step of research. It requires to design data transfer between neural network application and DP2PNSolver system. The transfer is needed to provide effective research of entry data and analyze of outcomes.

We can assume any further extension might be added to three pillars R&D sector model in similar approach as it was extended for innovation matters.

3.4 CONCLUSION

R&D sector is part of comprehensive systems then only systematic approach might help to understand what might be done to improve sector and how to mitigate weakness. Taking into consideration complexity of

economy I would state study the possibility of improving the results of the R&D sector is very interesting research. This is important we could react proactive to ensure sector development is sophisticated then R&D sector can aim state economy.

System proposed by author is intend to research what is the best utilization of existing resources in order to get sophisticated R&D sector return for economy. This paper was extension of support system by consideration whether invitation prioritize can change overall system design. This is outcome pointing out system is reluctant on adding innovation to overall R&D sector model. Support system presented by author is reluctant on changes might happen when innovation effort will be enclosed for R&D sector.

References

1. Chmielewski J., Dynamic Programming for R& D Sector Development, Analiza systemowa w finansach i zarządzaniu – wybrane problemy tom 4(16), Instytut Badań Systemowych PAN, 2014.
2. Duval, R., de la Maisonneuve C., Long-Run GDP Growth Framework and Scenarios for the World Economy, OECD Working Papers No 663, 2009.
3. Duzinkiewicz K., Grochowski M., Metody sztucznej inteligencji, Politechnika Gdanska, Wydzial Elektrotechniki i Automatyki, Katedra Inżynierii Systemow Sterowania, Metody sztucznej inteligencji, Zajęcia laboratoryjne, 2012.
4. Gajda J., Gustafson C., EMIL - An Econometric Macro Model of Sweden, Orebro University Department of Economics, 1999.
5. Johansson A., Long-Term Growth Scenarios, OECD Economics Department Working Papers, No. 1000, OECD Publishing, 2013.
6. Johansson A., Looking to 2060: Long-Term Global Growth Prospects: A Going for Growth Report, OECD Economic Policy Papers, No. 3 - OECD Publishing - ISSN 2226583X, 2012.
7. Lew A. , Mauch H , Dynamic Programming, a Computational Tool, ISBN-10 3-540-37013-7, Springer Berlin Heidelberg New York, 2006.
8. Łata M. , Smart Growth Operational Programme, 2014-2020, Ministry of Regional Development , Annual Conference of Competitiveness Operational Programmes, 2013.
9. Mauch H., DP2PN2Solver: a flexible dynamic programming solver software tool, Control and Cybernetics, 2006, Vol.: 35, Part 3, pages 687-702, Polish Academy of Science, 2006.
10. Rościzak P., Model gospodarki Szwecji EMIL w postaci sieci neuronowych. http://www.rosczak.com/index.php/pl/oprogramowanie/emil, 2003.
11. Severac Z., Koprivica M. , Getting started with Neuroph, Neuroph Studio framework version 2.3, 2012.
12. The Organisation for Economic Co-operation and Development 1, Medium and Long-term Scenarios for Global Growth and Imbalances, OECD Economic Outlook - Volume 2012 Issue 1 - OECD Publishing, 2012.
13. The Organisation for Economic Co-operation and Development 2, OECD Economic Outlook, Vol. 2012/2 OECD Publishing, 2012.
14. The World Bank., Innovation in Poland – Addressing the Euro 10 billion Question, The World Bank, 2013.

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Streszczenie. W artykule przedstawiono propozycję utrzymania systemo-wego podejścia do zagadnienia rozwoju sektora B+R w Polsce w okresie dużego nacisku na działania innowacyjne. Proponowany system jest to rozszerzenie odwzorowania sektora B+R zaproponowanego wcześniej przez autora. System wykorzystuje sieć neuronową, która stanowi obiekt dla programowania dynamicznego w zadaniu poszukiwania lepszego rozwiązania. Zaproponowany model okazał się na tyle elastyczny, że również nakłady na innowacje mogą być w modelu uwzględnione.

Słowa kluczowe: innowacje, sektor badawczo-rozwojowy, sieci neuronowe, programowanie dynamiczne, zadanie poszukiwania lepszego rozwiązania

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