Financial Internet Quarterly „e-Finanse" 2018, vol.14/ nr 1, s. 1-11
DOI: 10.2478/fiqf-2018-0001

APPLICATION OF PROBABILISTIC INFERENCE IN DEFINING IMPACT OF THE GENERAL GOVERNMENT SECTOR'S SIZE ON THE ECONOMY AND DETERMINING THE SIZE OF THE SECTOR BY THE ECONOMY IN THE EU

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Abstract

The article's objective is to apply probabilistic inference in determination of the impact of the size of the general government sector on the economy and the impact of the economy on the size of the sector in EU Member States. The research indicated that 4 of 13 variables describing the size of the general government sector have a significant impact on the economic parameters and determined their value and that impact of the economy on the general government sector is significantly more identified than determination of the economy by the sector size.

JEL classification: E62, H11, H20, H50, H60
Keywords: General government sector size, economy, public finance, impact of size of general government sector on the economy, Bayesian networks, probabilistic inference

Received: 02.01.2017 Accepted: 20.09.2017

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Introduction

The issue concerning relationships between the general government sector and the economy is for a variety of reasons as interesting as it is difficult. There are a number of factors that together describe the relationship and which despite the relatively frequent attempts and approaches to analysis the issue remains not fully explored, thus not fully explained.

The first of the problems associated with analyses which are dedicated to the general government sector is the question of whether the public sector or in particular the general government sector (which is not managed in its activity by the criteria of profitability, but the satisfaction of collective needs of the community through the provision of generally accessible services (cf. System of National Accounts, 2008, p. 436) should be subjected to typical economic analyses. There is a certain conflict that speaks for this doubt. It occurs between measurement of the cost effectiveness of public tasks, which due to its nature is characterized by scarcity, and efficacy of their delivery. It is hard to question the efficacy of providing free access to the public education system, or health insurance. While it is difficult to evaluate the delivery of elementary public goods and social services by the general government sector - that is, the effective implementation of public tasks (cf. Kleer, 2005), it naturally raises questions about the efficiency of spending public associated with their implementation (see. Skica, Pomianek, Pater, Tarnawska, 2009; Skica, 2011; Skica, 2014). Importantly, although the issue of the effectiveness of public expenditure is a subject widely discussed in the literature (undertaken by inter alia Gupta & Verhoeven, 2001; Joumard, Kongsrud, Nam, Price, 2004; Pevcin, 2004; Afonso, Schuknecht, Tanzi, 2005, 2010; Mandl, Dierx, Ilzkovitz, 2008; Tsouhlou & Mylonakis, 2011), it still remains topical due to new threads, new - original research initiatives, as well as lessons learned from them.

Secondly, it is problematic to select measures to express the size of the general government sector. There are currently in the literature both measures based on public expenditures and public income as well as size of the employment in the sector (i.e. public administration). Public spending compared to GDP is used as a measure of the public sector (including size of the general government sector), in the research papers of inter alia Pevcin (2004), Afonso, Schuknecht and Tanzi (2005), as well as Kustepeli (2005). This measure of the sector is also used by Jiranyakul and Brahmasrene (2007), Romero-Avila and Strauch (2008), Chobanov and Mladenova (2009), Dilrukshini (2009), as well as De Witte and Moesen (2010). Ratio of public spending to GDP is also applied in the scientific articles of Bergh and Henrekson (2011), Forte and Magazzino (2011), Theodoropoulos (2013), Marsh and Dewar (2013), Afonso and Jalles (2013), and finally Di Matteo (2013). On the other hand, a measure that is based on public income referring to GDP is used by, among others, Rubinson (1977) and Korpi (1985), and the ratio of public income components' structure was used by the following authors as a measure of public sector size: Romero-Avila and Strauch (2008). Ultimately, the measure of the size of both the whole public sector and the general government sector, as well as its individual components, is the number of people employed in the sector. This ratio was used by, among others, Labonte (2010), Anderson (2012), Garand, Ulrich and Xu (2014), and Bardes, Shelley and Schmidt (2015). Importantly, despite many attempts and approaches to measure the size of the general government sector, there is no clear answer to the question of which of the measures referred to above should be considered the best one for description of the size of the sector. This situation means that continuous attempts are being made to redefine traditionally used measures of the size of the general government sector and at the same time, scientific research is launched in order to apply the proposed measures in the study on impact of the size of the sector on the economy.

The third problematic area for analysis dedicated to the public sector (including the general government sector) that is associated with the aforementioned definitional problem is to determine the answer to the question of whether the size of the general government sector affects the performance of the economy, or whether it is itself determined by the economic condition of a country. Results from ongoing studies seem to indicate a third direction in analyzing the dependencies outlined above. More and more often the authors prove bipolarity of dependencies on the line: the size of the sector - the economy. Results of Skica, Rodzinka and Mroczek (2016) confirm both the impact of the size of the general government sector on the economy and the impact of the economy on the size of the general government sector (Skica, Rodzinka, Mroczek, 2015a; Skica, Rodzinka, Fryc, 2015b). This way, the certain stereotype that is available in the literature is being broken down to stress a simple, one-way relationship between the variables.

The research problems that were presented above are materialized in principle irrespective of the manner and approach to research. They justify the attempt taken by the authors of this article to investigate the phenomenon of the impact of the size of the general government sector on the economy and the impact of the economy on the size of the sector.

In the research the authors used quantitative data for EU Member States that were collected for the years 2000-2013 (inclusive) from the Eurostat, OECD and World Bank databases. The collected data has been prepared for analysis: incompleteness and noise have been eliminated and discretization and integration have been performed. More details about the preprocessing data is available in Skica et al. (2016).

Our previous research on the determination the relationships between the economy and the general government sector size (Skica et al., 2015a) and on the identification of the relationship between the general government sector size and the economy (Skica et al., 2016), were based on a qualitative component belief network analysis, i.e. a network structure. Our current research is based on a quantitative component belief network analysis, i.e. a probability distribution. It seems that the analysis of this belief network component may lead to a deeper insight into the structure of knowledge hidden in the analyzed data, because it provides information about cause and effect relationships between nodes (attributes).

Bayesian networks inference

Bayesian networks are a complex representation of knowledge about casual relationships between properties of attributes. The complexity of the network is determined by the combination of the probability distribution concept and the learning model of the considered problem, forming a directed, acyclic graph in which nodes represent objects and arcs - probability relationships. Analysis of a quantitative belief network component provides information about cause and effect relationships between nodes (attributes).

Nodes represent the predicates (logical sentences), whose verity is based on the predicates that are represented by nodes connected to them. The measure of the verity of these predicates is probability and the description of the correlation is the cumulative probability distribution - the product of the conditional probability distributions:

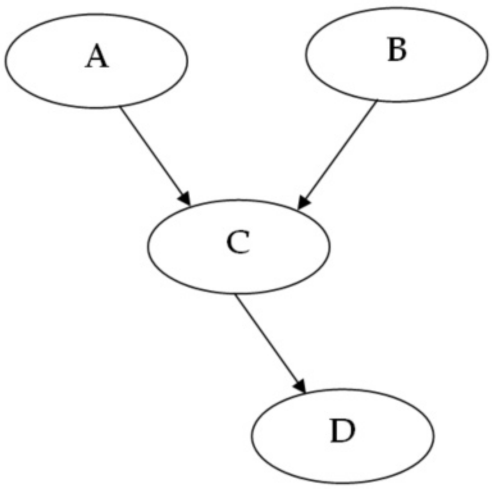
$$P(X) = \prod_{i=1}^{n} P(X_i | pa(X_i))$$

where X={X1 , X2 ,..., Xn},

pa(Xi) determines a set of parents for Xi attribute.

Refer to the example Bayesian network shown in Figure 1. The network is a set of nodes (attributes) X = {A, B, C, D}, each attribute having values <Yes, No>. P(C|AB) is an example of a conditional probability; P(A) is an example of a prior probability. The network's joint

Figure 1: A Bayesian network



$P(A) =$

Yes	No
0.5	0.5

$P(B) =$

Yes	No
0.5	0.5

$P(C|AB) =$

A	B	P(C|AB) Yes	No
Yes	Yes	0.7	0.3
No	No	0.3	0.7
Yes	No	0.7	0.3
No	Yes	0.7	0.3

$P(D|C) =$

C	P(D|C) Yes	No
Yes	0.2	0.8
No	0.1	0.9

Source: Own elaboration.

probability distribution is the product of the conditional and prior probabilities:

$$P(X) = P(A)P(B)P(C|A,B)P(D|C)$$

Due to the fact that the Bayesian network determines a joint probability distribution it can be used for inference (Pearl, 1988). Probabilistic inference in Bayesian networks is based on updating the conviction of the truth of the hypotheses in the case of certain observations (prerequisite), so on the determination of the conditional probability distribution P (H | E) for the hypothesis H, where E is the set of observations.

The most common inference methods are predictive inference (from causes to effects) - from new information about causes to new beliefs about effects, according to the directions of the network arcs and diagnostic inference – (from effects to causes), effects are known to look for causes, in the opposite direction to the network arcs instead of exact inference. There are also known intercausal inference (between parallel variables) – the mutual causes (effects) of a common effect (cause) and combined inference – in exceptional cases inferences are a combination of several types of inference.

Regardless of the Bayesian network structure, there is special case concerning inference (the designation of a probability distribution for a single hypothesis), as well as the general case (the designation of a probability distribution for all hypotheses).

Refer to the example in Figure 1, the diagnostic support might consider for the belief on A = Yes, given the observation that D = Yes. Such a support is formulated as follows:

$$P(A = Yes|D = Yes) = \frac{P(A = Yes, D = Yes)}{P(D = Yes)}$$

where

$$P(A = Yes, D = Yes) =$$

$$= \sum_{B,C \in <Yes,No>} P(A = Yes)P(B)P(C|A = Yes, B)P(D = yes|C)$$

and

$$P(D = Yes) =$$

$$= \sum_{A,B,C,D \in <Yes,No>} P(A)P(B)P(C|A,B)P(D = Yes|C)$$

The full summation over variables is called exact inference. The most known algorithm to solve the exact problem is variable elimination (cf. Zhang & Poole, 1996; Dechter, 1999). The algorithm works by implicitly constructing the joint probability distribution induced by the Bayesian network, and then summing out attributes, therefore constructing a marginal distribution over the variables of observed. Advantages of this algorithm include its generality and simplicity.

Bayesian networks have been applied in a wide range of areas in health services research: health economic evaluation, health quality measurement, health outcomes monitoring, cost-effectiveness analysis but also in epidemiology, clinical research, medical decision making, public health or economy (recently: Gadewadikar et al., 2010; Harding, 2011; Cobb, 2011; Sesen et al., 2013). In our research we used them and diagnostic inference to estimate impact of the size of general government sector on economy, as well as impact of the economy on the size of the general government sector.

Experiments and results

In our previous research (Skica et al., 2016) the learning models in form of Bayesian networks were generated for each year separately. Consequently, it could lead to the dispersion of information hidden in the data. In order to eliminate this problem, the data have been grouped by years for each of the dependent variables. To define the impact of the size of the general government sector on the economy and in determining the size of the sector by the economy, the authors used an advanced mathematical model called diagnostic inference (discussed in the previous section). The inference was conducted with application of a Bayesian network. In the first case (estimation of impact of the size of the general government sector on the economy) 18 learning models in the form of Bayesian networks were generated. In each model, the authors used the same set of descriptive variables, from the field of general government sector, to study their impact on particular variables in the field of the economy. In contrast, to determine the size of the general government sector by the economy, 15 learning models in the form of Bayesian networks were generated. In each model the authors used the same set of describing variables, from the areas of the economy, to study their impact on particular variables from the field of the size of the general government sector.

Diagnostic inference was conducted by specification of particular categories of the dependent variable and the observation of probability distributions of the describing attributes. It was assumed that the finding of conducted inference was those of values of the observed attributes that by the inference reached the level of probability greater than 0.5. The probability value is higher, the effect is stronger. At the same time, it was found that the attributes whose values achieved a level of probability equal to 0.5 should be excluded from the set of explanatory attributes, because the lack of a clear indication of their value suggests that the attribute does not significantly affect the results of inference. In the research, the authors assumed that impact on the level that is greater that 0.5 is a positive impact. It means that a probability value which is greater than 0.5 proves that larger impact of the sector affects the economy in a positive way. The higher the probability is, the stronger this positive effect. At the same time, the positive value of the probability in the case of economic variables means that impact on the sector's size is positive and on the other hand the greater the value of the probability, the stronger the positive impact on sector size.

The best results of diagnostic inference were collected in Table 1 (presenting impact of size of the general government sector on the economy) and in Table 2 (presenting impact of the economy on the size of the general government sector). In Table 1, the column names are the decision variables from the economic field, whereas the row names are the describing variables from the area of the size of the general government sector. In Table 2, column names are the decision variables from the area of size of the general government sector, and the names of rows are describing variables from the economic field. Specifying the categories of these decision variables, the authors observed probability distributions of the describing variables. Thus, at the intersection of a column, there was given a value of probability.

Description 0.639 in Table 1 (at the intersection of the first column of 1- activity rate (in %) and the third row of C - public sector employment (number of people)) means that for a fixed value of the variable activity rate the probability of the variable public sector employment is 0.639. In other words, the variable public sector employment has a positive impact on economy and the impact is 0.639. Empty cells in Table 1 and Table 2 indicate that the observed attributes do not affect the result of inference, as it reached the level of probability of less than 0.5. In addition, the authors highlight Table 1 and Table 2 with orange color in those cell in which the effect size was above 0.7, with gray color larger than 0.8, while yellow color indicates values larger than 0.9.

Table 1: Results of diagnostic inference of the size of the general government sector on the economy in the EU

	1	2	4	5	6	7	8	9	10	12	11	13	14	15	16	17	18
A					0,508											0,51	
B				0,551					0,593				0,759	0,717		0,72	
C	0,639	0,517	0,522	0,526	0,735	0,688	0,658	0,698	0,605	0,505	0,502	0,618	0,53	0,524	0,589	0,533	0,51
D	0,654	0,573	0,666	0,929	0,885	0,758	0,625	0,613	0,54	0,713	0,56		0,58	0,775	0,531	0,677	0,8
E	0,724	0,55	0,652	0,9	0,756	0,798	0,691	0,681		0,747	0,503	0,568	0,516	0,782	0,58	0,626	0,681
G				0,502									0,51	0,571			
I				0,555					0,598				0,516	0,529		0,567	
J				0,579	0,532	0,505			0,596			0,55	0,686			0,532	
K	0,801	0,744	0,731	0,857	0,804	0,835	0,764	0,78	0,85	0,813	0,728	0,813	0,828	0,859	0,808	0,829	0,803
L				0,529													
M													0,526	0,516			
N		0,5									0,524						
O					0,514												

Table 2: Results of diagnostic inference of the economy on the size of the general government sector in the EU

	1	2	4	5	6	7	8	9	10	12	11	13	14	15	16	17	18
A					0,508											0,51	
B				0,551					0,593				0,759	0,717		0,72	
C	0,639	0,517	0,522	0,526	0,735	0,688	0,658	0,698	0,605	0,505	0,502	0,618	0,53	0,524	0,589	0,533	0,51
D	0,654	0,573	0,666	0,929	0,885	0,758	0,625	0,613	0,54	0,713	0,56		0,58	0,775	0,531	0,677	0,8
E	0,724	0,55	0,652	0,9	0,756	0,798	0,691	0,681		0,747	0,503	0,568	0,516	0,782	0,58	0,626	0,681
G				0,502									0,51	0,571			
I				0,555					0,598				0,516	0,529		0,567	

J				0,579	0,532	0,505			0,596			0,55	0,686			0,532	
K	0,801	0,744	0,731	0,857	0,804	0,835	0,764	0,78	0,85	0,813	0,728	0,813	0,828	0,859	0,808	0,829	0,803
L				0,529													
M													0,526	0,516			
N		0,5									0,524						
O					0,514												

The names of the economic variables are coded with numbers from 1 to 18, whereas names of variables describing size of the general government sector are coded by the letters from A to O, as follows:

1- Activity rate (in %), 2 - Balance of the current account (million euro), 3 - External balance of goods and services (million euro), 4 - FDI - foreign direct investment (million USD), 5 - Gross domestic product in current prices per inhabitant (GDP per inhabitant), 6 - Harmonized indices of consumer prices (HICPs) (annual average rate of change), 7 - Human development index – HDI (value from 0 to 1), 8 - Inward FDI flows (million USD), 9 - Outward FDI flows (million USD), 10 - Potential output of total economy (dynamic annual average rate of growth - percentage), 11 - Real effective exchange rate (index 1999 = 100), 12 - Production in industry – dynamic (percentage change compared to same period in previous year), 13 - Unemployment rate (in %), 14 - Growth rates of GDP (percentage change), 15 - Retail sales - dynamic Index of turnover (total 2010 = 100), 16 - Potential output of total economy (million euro), 17 - Gross capital formation (% GDP), 18 - Gross domestic product in current prices per inhabitant - dynamic (percentage change).

A - General government gross capital formation (% GDP), B - Government consolidated gross debt (% GDP), C - Public sector employment (number of people), D - Total general government expenditure (euro per inhabitant), E - Total general government revenue (euro per inhabitant), F - Net lending/ borrowing (million euro), G - Total general government expenditure (% GDP), H - Central government deficit (% GDP), I - General government sector output (% GDP), J - Gross value added (general government total value-added) (basic (current) prices), K - The ratio of total taxes to GDP (% GDP), L - Final consumption expenditure (% GDP), M - General government deficit (% GDP), N - Total general government revenue (% GDP), O - General government gross fixed capital formation (% GDP).

Source: Own elaboration.

The data presented in Table 1 needed to be analyzed in two complementary ways. The first of these was the analysis designed to demonstrate which of the variables describing the size of the general government sector are affecting the economy as a whole in the strongest way. This means that in relation to these sector parameters, the authors recorded the largest number of probability values that exceeded the level of 0.7 as well as 0.8 and 0.9. The second dimension of analysis was to combine individual sectoral variables that most strongly affect the economy (selected in the first stage of the research), with the individual parameters describing the sector of the economy (i.e. variables that were the most strongly affected by the sector variables).

Analysis of the first of the appointed approaches allows us to notice that a variable describing the size of the general government sector which had by far the greatest impact on the whole economy was a parameter called the *ratio of total taxes to GDP (% of GDP)*. This variable had the widest range of effects on economic variables, because it had impact on all of the variables describing the economy with probability above 0.7. In the next places there were three sector variables: *total general government expenditure (euro per inhabitant), total general government revenue (euro per inhabitant) and public sector employment (number of people)*. The indicated variables (4 from 13) describing the size of the general government sector put the largest impact on the economic parameters and determined their value.

The second of the approaches allowed us to observe that the influence of the general government sector is the widest in the case of four economic variables - *gross domestic product in current prices per inhabitant (GDP per inhabitant), growth rates of GDP (percentage change), retail sales - dynamic Index of turnover (total 2010 = 100), gross capital formation (% GDP)*. These economic variables affect at least eight variables from the general government sector wherein six variables: *government consolidated gross debt (% GDP), public sector employment (number of people), total general government expenditure (euro per inhabitant), total general government revenue (euro per inhabitant), general government sector output (% GDP), the ratio of total taxes to GDP (% GDP)* are common.

Table 2 presents the results of diagnostic inference of the economy on the size of the general government sector. In Table 2, column names are the decision variables from the field of the size of the general government sector, and the names of rows are variables describing the economic field and similar to Table 1, blank cells indicate that the observed attributes do not affect the result of inference, as it reached the level of probability that was less than 0.5. The first phase of analysis on the data collected in Table 2 was to examine which of the variables that describe the economy affect the size of the general government sector to the greatest extent. For this purpose, the authors focused on establishing relations to the economic parameters where there were the largest number of probability values that exceeded level 0.7 as well as 0.8 and 0.9. The analysis proved that a variable describing the economy which had decidedly the strongest impact (averaged probability is 0.82) on the size of the general government sector, was the parameter called *real effective exchange rate (index 1999 = 100)*. In the next places (averaged probability is 0.8) were the following economic variables: *balance of the current account (million euro), external balance of goods and services (million euro)*, as well as *FDI - foreign direct investment (million USD)*. The third group (averaged probability is 0.7) are the economic variables: *activity rate (in %), gross domestic product in current prices per inhabitant (GDP per inhabitant), inward FDI flows (million USD) and outward FDI flows (million USD)*. These variables and additionally *human development index – HDI (value from 0 to 1)* as well as *potential output of total economy (dynamic annual average rate of growth - percentage)* have the widest range of effects on the general government sector variables, because they had impact on all of the variables describing the general government sector.

Conclusion

The analysis presents a substantial number of findings which on the one hand provide answers to the questions raised in the article, and on the other hand, set new questions that require an examination in the course of further work on the impact of the size of the general government sector on the economy and determination of the size of the general government sector by the economy.

The general conclusion of the study is the fact that impact of the economy on the size of the general government sector is considerably more strongly identified, than the determination of the economy by the size of the general government sector. This fact is significant due to the situation that although the scientific literature demonstrates a mutual dependence on the line: size of the sector - the economy and the economy - the size of the sector, there is much more frequent identification of impact of sector variables on the economy, not vice versa. The study therefore constitutes significant added value in explaining the dependencies.

These dependencies between the size of the general government sector and the economy were primarily described by the impact of probabilities values that ranged from 0.5 to 0.7. In second place, there were dependencies described by the impact on the level that was higher 0.7, but at the same time less than 0.8. In only a few cases, the authors recorded influence of sector variables on the economy that exceeded the value of 0.8 and in the case of only one dependency an impact that exceeded the value of 0.9. In the case of dependency on the line: economy - size of the sector, despite the fact that similarly to the previous case it described primarily impact on the probability level from 0.5 to 0.7, the impact described by values from 0.7-0.8 and 0.8-0.9 was still most frequently identified. What is important is that in the case of impact of the economy on the size of the sector, the authors found 11 occurrences where this impact had probability values on the level exceeding 0.9.

The variable that describes size of the general government sector which had decidedly the strongest impact on the whole economy was the parameter called the ratio of total taxes to GDP (% of GDP). In the next places there were two sector variables: total general government expenditure (euro per inhabitant) and total general government revenue (euro per inhabitant). The generic categories of the variables describing size of the general government sector put the largest impact on the value of economic variables. Nevertheless, the variable that describes the economy and that had the strongest impact on the size of the general government sector was the parameter called the real effective exchange rate (index 1999 = 100). The next places were taken by: balance of the current account (million euro), external balance of goods and services (million euro), FDI - foreign direct investment (million USD) activity rate (in %), gross domestic product in current prices per inhabitant (GDP per inhabitant), inward FDI flows (million USD) and outward FDI flows (million USD). Due to this fact, these variables describing economy had the largest impact on the sector parameters and determined their values.

The conducted analysis constitutes the starting point for attempts to optimize the size of the general government sector that were made in a cross-section of national economies of the EU Member States which were examined. The research findings have proved an interesting dependence, yet they were identified on the data received after combining the economic and sector data for all examined EU countries. Taking into account the diversity of the results of strengths of influence (expressed by the probability value) and the direction of this impact (i.e. the impact of the economy on the size of the sector and / or influence on the size of the sector on the economy), it is necessary to bring this analysis to the level of each of the EU Member States individually, to identify the degree of universality of the dependencies that were found and described, and then to attempt to optimize the size of the general government sector from the perspective of both its impact on the economies of the examined countries and determination of its size by the national economies. These issues will be the subject of separate research dedicated to explaining the phenomenon of the impact of the size of the general government sector on the economies of the examined EU countries.

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