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Sustainable growth of EU economies and Baltic context: Characteristics and modelling

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Abstract. The united general growth strategy for all EU Member States, a common economic and political vision as well as location in the same geographic region provides a necessary basis for the benchmarking modelling of economies. The main objective of this study is determination of the functional regularities and drivers of the growth of EU economies and the context of the Baltic States in line with the general trend of the EU, as well as development of the growth model, which can be used for sustainable planning and prediction. Analysis of several regularly published analytical indexes suggests a thesis on innovation as the real basic driving force for EU economies and outlines Innovation Performance Index, which have a very strong compliance with the economic growth of particular country. At the same time study of the data set and methodology of the Index indicates space for further optimization. By use of several linear regression tools the growth model was created. It is based on three hard independent statistical indicators (predictors) only; of course, these indicators is a peak of a complex pyramid. Despite of the simplicity of the model, the long-term correlation of fitted values with the real GDP per capita is extremely strong 0.961 – 0.987).

Keywords: economic indicators, gross domestic product, economics planning, innovation, data analysis, mathematical models.

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1. INTRODUCTION

The sustainable growth of any economy depends on many aspects with different impact on general progress, which are widely discussed in the contemporary scientific literature (e.g. Bilan et al. 2017; Korauš et al. 2017; Jurigová et al. 2016; Čirjevskis 2016; Štitilis et al. 2016; Laužikas et al. 2016; Strielkowski 2016; Tvaronavičienė 2016a, 2016b; Pauceanu 2016).

Planning the growth, modelling is proposed as a tool, which makes it possible to evaluate scenarios and strategies, to select the aspects with significant effect and to predict the future (e.g., Divya & Devi, 2014; Stundziene, 2015).

There is a united general growth trend for all EU countries. In 2010 the European Commission (EC) launched the complex coherent "Europe 2020 Strategy" to turn the EU into a smart, sustainable and inclusive economy (EC 2010a). Of course, this does not exclude the exploitation of national comparative advantages, e.g., industry, tourism, agriculture; nevertheless a common economic and political vision, the location in the same geographic region provides a necessary basis for benchmarking modelling of economies.

There are advantages for the Baltic States (BS) in this case. The growth regularities of EU economies, which are on the similar development level, can be used for the benchmarking. And what is even more important: there are number of economies, which currently are on higher level; their experience will be important for planning our activities and prediction of progress.

Regular analytical reports, which contain evaluation and ranking of economies on the global or regional scale in some aspect, are a significant enabler of successful benchmarking. Diverse complicated indexes are created for this purpose by the aggregation of huge number of indicators using various methodologies. They declare the most competitive (GCI, 2016/17), better governed (WGI, 2016) and less corrupted (CPI, 2016) country, the most smart (GII, 2016; EIS, 2016) and technologically advanced (WDR, 2017; IDI, 2016; DS, 2016) economy with well-developed markets (PMR, 2013), where it is easy to do business (DB, 2016; GEM, 2016/17).

Actually all mentioned and similar issues are not the end in itself; the interest on them is subordinated to growth of economic prosperity and/or humans' wellbeing level (e.g., the human development (HDI, 2015), happiness (WHR, 2016) or life satisfaction (Eurostat, 2017)). However the consistency of mentioned complicated indexes with the progress in sustainable growth is not reflected in reports. Furthermore, their correlation with the general economic and welfare indicators is far from perfect. "…we see a week direct connection of the Doing Business index with economic welfare" (Messaoud and Teheni, 2014); also: "…the gap between the Doing Business ranking and average income is hefty… Such disparities feed concerns about shortcomings in the Doing Business report" (The Economist, 2015). And more: "…(innovation performance) ranking does not take specific economic and social conditions of the country into account" (Nasierowski and Arcelus, 2012). Several studies indicate differences in compliance of indexes with processes in high- and low-developed economies (e.g., Kordalska and Olczyk, 2016; Crespo and Crespo, 2016), or bias towards high-tech sectors (e.g., Janger et al, 2017) that indicate weaknesses of the methodologies.

In total it shows the questionable direct usefulness of the indexes for the strategic planning of sustainable development as well as for the assessment of implemented activities. The number of analytical publications pay attention to the serious weakness of index-seeking policy (that is popular in BS); e.g., "The indexes may be poor guides for policies as each link between indicators and scores is noisy and uncertain, but presented as certain" (Hoyland et al, 2012). Previous proposals to improve methodologies (e.g., Donoso,

2017) or to introduce new indicators (e.g., innovation efficacy instead of performance (Mahroum and Al-Saleh, 2013)) have not solved aforementioned problem.

At the same time reports, which are created by experts of prominent bodies (United Nations, OECD, World Bank, World Economic Forum, EC, etc.), contain the valuable information. Analysts point also to the some mutual cross-linkage; e.g., the improvement of innovation performance leads to the growth in competitiveness too (Ciocanel & Pavelescu, 2015).

The main objective of this study is determination of the functional regularities and drivers of the growth of EU economies and the context of the BS in line with the general trend of EU, as well as development of the benchmarking model, which can be used for the growth modelling of the EU Member States, including the BS. Several most encouraging analytical indexes are analysed to indicate the potential basis for the data mining process.

2. METHODOLOGY

Determination of a dependent variable, which is growth-oriented hard indicator and reflects the progress, is the first task.

The "Europe 2020 Strategy" stipulates to achieve the growth through development of "social market economy" that will reinforce the progress in education, employment, social cohesion too. Without any doubt, better life, higher standard of living is priority for everybody and therefore for all society and government in any country (e.g., Karnitis, & Kucinskis, 2015; Dirzytė et al. 2016; Tunčikienė, & Drejeris 2015; Rezk et al. 2015; Horváthová et al. 2016; Dobele et al. 2015).

Because of multi-dimensional essence of the quality of life, its quantitative level cannot be characterized by one sectoral numerical indicator; set of many indicators as well as their aggregating should be elaborated for direct quantitative evaluation (e.g., the World Happiness Report (WHR, 2016) uses a complicated methodology to create integrated scores).

In addition, the mentality and requirements of people (soft data!) are very different (it relates even to members of the same community in the same country, not speaking on various nations in the EU); the priorities are changing (e.g., in addition to traditional economic and social priorities also migration and security/terrorism issues have becoming important for citizens of several EU countries (Eurobarometer, 2016)). It weakens the sustainability of the evaluation and sharply increases the uncertainty of the scores even on regional scale. For this reason the Eurostat (as well as the OECD) does not create a composite indicator for the quality of life.

The composition of the World Happiness Index (WHI) scores (fig. 1a) indicates the material factor (gross domestic product per capita (GDP pc)) for EU nations on the level 19-26% of total happiness scores. At the same time the correlation of WHI scores with GDP pc is very strong (fig. 1b); it shows much higher real impact of economic factor through the public services – healthcare, education, culture and other aspects; the economy is a real basis for all these services. Correlation of the Human Development Index (which also reflects the welfare level of population) with GDP pc for EU countries is even stronger – 0.89. It is obvious that "the relationship between competitiveness and wellbeing is becoming stronger and mutually supportive" (Balkyte and Tvaronavičiene, 2010). Such consistency clearly shows that "… the economic measure probably can be used if not as a welfare indicator, but an approximation" (Schuller, 2014).

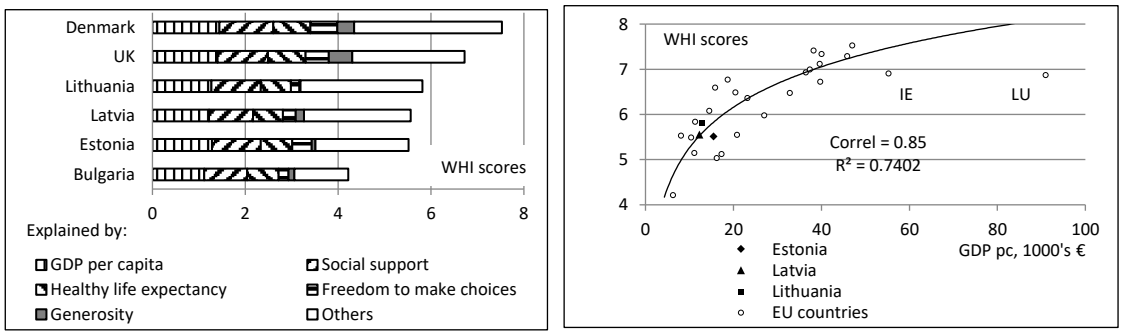

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Figure 1. WHI: (1a) – scores of index for selected countries, 2015; (1b) – correlation with GDP pc, EU countries

Source: WHI, 2016

More than 80 years gross domestic product serves as the major economic indicator and a yardstick for the measurement of economic achievements (e.g., Fioramonti, 2014); its derivative GDP pc is widely used as an indicator of the material welfare level in the corresponding country and driver of public policy. A criticism of GDP shortcomings (related to income distribution, informal economy and environmental issues) also is quite widespread (e.g., Jeroen, 2009); even the EC has declared a necessity to "… complement GDP with additional indicators" (EC, 2009). Nevertheless, the GDP has maintained its position of the headline economic indicator. We also will use the GDP pc as the dependent (target) variable for the growth model.

Fig. 1b clearly indicates two outliers. Economy of the Luxembourg is based on off-shore banking and wide location of EU-scale institutions and therefore really does not depend on the local aspects. Ireland has hosted central offices of several multinational companies; all turnovers of these companies since 2015 formally relates to the Ireland economy. Analogous disparities we can indicate also in regularities that will be analysed in next chapters. According to the theoretical research in data mining, it is reasonably to carry out the analysis and to develop the data models excluding such exemptions instead of use of the full data pack (e.g., Barzdins et al, 1993). Therefore further analysis is performed using the data of 26 EU countries.

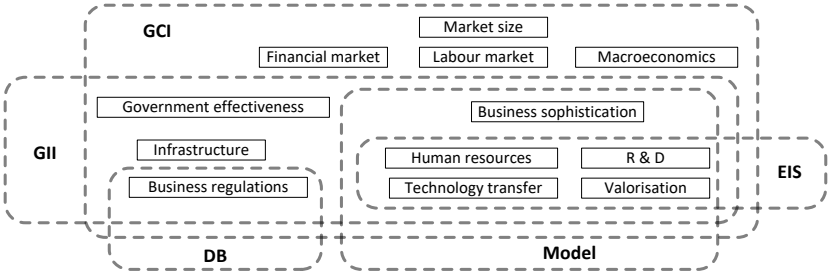

Figure 2. Functional clusters of indicators and their use in particular index

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A natural strategy for the development of our model includes maximum usage of existing advantages of indexes. The total scope of characteristics, which are exploited as the key performance indicators to create indexes, is not infinitely large; a lot of simple and composite indicators are used repeatedly in number of

indexes. Overall, the indicators can be arranged in series of functional clusters; various indexes use narrower or larger data set from the total scope (fig. 2). Presumably the predictors for our model first and foremost should be selected from these clusters.

There is a high proportion of subjective viewpoints (soft data) among the components of many indexes; cross-analysis of several of them identifies the impact of subjectivity and/or mentality on scores. E.g., the objective evaluation of efficiency of customs procedures in the Doing Business Report (DB), which are based on figures of time and cost, shows quite similar ranks for the BS, while opinions of the Global Competitiveness Index (GCI) respondents on efficiency of the customs are very different (fig. 3a). Similarly, the government effectiveness (Worldwide Governance Indicators (WGI)) is an aggregated indicator of ca. 50 various components from 15 sources, while functionally analogous component (*Public institutions*) of the GCI, which covers the similar scope of functions, reflects only fully subjective viewpoints of respondents (fig. 3b). It could be concluded with a high probability that Latvians are much more critical than Estonians, but mentality of Lithuanians is in between. We will include only the hard data in the set of searched indicators.

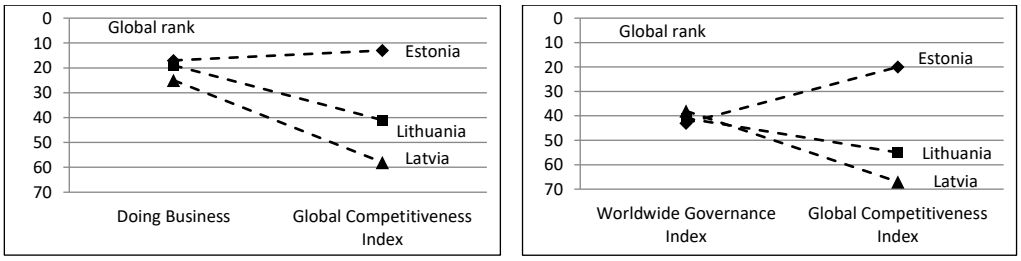

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Figure 3. Differences among objective indicators and subjective viewpoints: (3a) – customs scores, (3b) – evaluation of government effectiveness.
Sources: DB, GCI, WGI

The data mining process will consist of two phases:

1. Analysis of the indexes/reports and identification of the scores that best of all correlates with the GDP pc for EU economies; the data set of this index would be used as a point of exit for the second stage.

2. Creation of the model – optimisation of the selected data set and synthesis of the general regularity to achieve the highest correlation of the model with the real GDP pc.

3. ANALYSIS OF ECONOMIC INDEXES

Doing Business Report (DB, 2016) and Global Competitiveness Index (GCI, 2016/17) are two the most popular annual reports that reflects a lot of aspects of the current situation in corresponding economies.

Doing Business – a business regulation

The DB report presents the detailed information on business regulations; the DB edition 2017 covers 10 areas of government regulation in 190 countries. The great advantage of the DB reports is the use of hard indicators only. When the numerical indicators are natural characteristics (e.g., cost, time, tax rate, number of procedures, etc.), objectivity is not a problem. The DB has achieved an objective assessment of

categories that cannot be characterized by exact indicators (e.g., extent of shareholder rights, strength of investor protection, quality of judicial process); for this purpose the particular category is described by the set of concrete facts and procedures and digital factual evaluation of their existence ("yes", "no", "partly").

The high quality of the business regulation is necessary for any model of economic growth. EU countries have already done a great job and developed a good environment for business. Fig. 4a shows good positions of the BS among EU countries in this aspect. Scores of the BS (fig. 4b) are high (gaps with EU overall leader (Denmark) are 5-7%) and very similar (mutual difference is less than 3%). All three BS have exceeded EU average scores, in several areas we have overtook the leader. Nevertheless, the DB scores identify some outstanding deficiencies that should be remedied in the BS (e.g., to increase the recovery rate during insolvency process, to strengthen the conflict of interest regulation for protecting minority investors, to improve the building quality control, to decrease the cost for electricity connection).

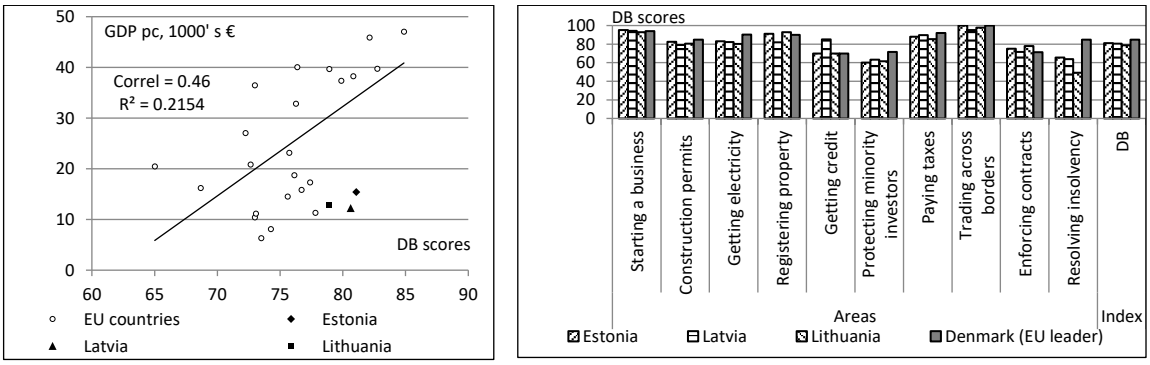

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Figure 4. DB 2017: correlation with GDP pc, 2015 (4a) and scores for the Baltic States (4b)

Source: DB 2017

At the same time the fig 4a indicates a week direct connection of the DB index with the economic welfare level in the EU countries. The coefficient of determination R^2 indicates that currently only around 20% of the GDP growth in EU economies could be determined by the increase of DB scores. Currently the further improvement of the DB index is not more the critical precondition for further growth of the BS as well as of all EU Member States; the stage of economic development, which focuses on the perfection of business regulations, has been concluded. The DB index and rank may not be more used as the indicator of economic development and, consequently, the target of policy in the BS (LRV, 2016; MKM, 2016; PKC, 2016). Although the DB supposedly does not pretend to this role (its slogan is "Measuring business regulations"), however indirectly the overall scores and ratings points to it. It should be mentioned that an independent panel of experts (appointed by the World Bank President!) in 2013 found number of weaknesses (including overall ranking) in the DB report and urged the Bank to consider their recommendations (IPR 2013); unfortunately the Bank has ignored them till today.

Due to very low correlation with the GDP pc the DB index cannot serve as the point of exit for creation of the EU-scale growth model.

Global Competitiveness Index – a multi-sectoral approach

The version 2016/17 of the GCI is aggregated from 114 components that are grouped into 12 pillars and 3 sub-indexes. Authors demonstrate well considered multi-sectoral approach to the competitiveness,

showing that it is not only the narrow economical aspect. Health and education, government effectiveness and security, R&D, business sophistication and innovation indicators are included in the set of characteristics. Such expert position would be helpful for the implementation of the EU recommendation on establishment of the analytical competitiveness and productivity boards in Eurozone countries (EU, 2016) as truly crosssectoral bodies.

A weakness of the GCI is 75+% of indicators, which are subjective viewpoints (soft data) of businessmen on processes in their country; actually the GCI is a perception index.

Methodological peculiarity of the GCI is grouping all economies in five clusters according to their stage of development (i.e., GDP pc). Very doubtful is the idea on the allocation of different specific weights of sub-indexes in the overall assessment for countries of various clusters; it means that sub-indexes and pillars affect overall scores of different economies in different way. Apparently it is a duty to creation of global-wide index and rating. Nevertheless, the result is astonishing scores and ranks for number of countries, e.g., factor-driven Rwanda (the lowest cluster, 700 $ pc in 2015, life expectancy 54 years) is ranked higher than innovation-driven Slovenia (20 700 $ pc); also Tajikistan (2 900 $ pc, lack of democracy) is ranked higher than Cyprus (23 500 $ pc).

Due to different evaluation of clusters, a mutual comparison of the EU economies cannot be exact; however, the correlation of the GCI with GDP pc is much stronger (fig. 5a) in comparison with the DB index (thanks to a comprehensive coverage of various areas).

Fig. 5 clearly shows a very negative issue too – some economic basis for two-speed Europe. A real reduction of apparent significant gap (value and dynamics of the GDP) between currently more successful Northern Europe and less successful Southern and Eastern Europe is a critical precondition not only for sustainable EU growth, but even for its continuance. The potential two-speed Europe, which is indicated several times during the data mining and modelling, would be a harmful option for the BS, though exactly this scenario ("Those who want more do more") experts recognized as the most real one among the scenarios presented in the White Paper (EC, 2017) for the future of EU27 after Brexit.

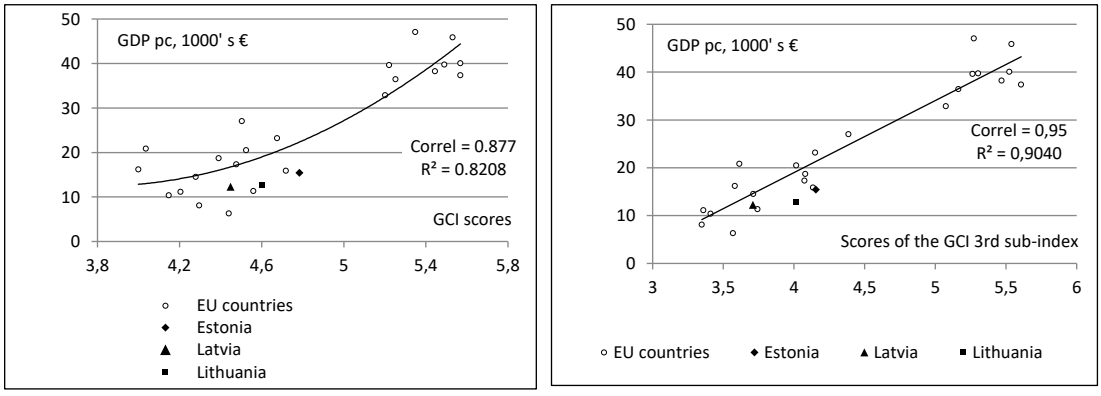

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Figure 5. Correlation of the GCI 2016/17 scores (5a) and scores of the 3rd sub-index of the GCI (5b) with GDP pc for EU countries (2015)

Source: GCI 2016/17

The BS are not ranked among the most competitive economies yet, there is a larger or smaller gap from the overall EU leader (the Netherlands) pillars' scores – up to 40% (fig. 6). Evaluations of the BS in

general are quite similar (mutual differences in majority of pillars' scores do not exceed 10%); Estonians are ranked higher, they have even overtaken the EU leader in two pillars.

Because of methodological shortages (biased scores and soft data), the GCI directly cannot be used as the point of exit for creation of the model. At the same time the division of economies in development-related clusters and different specific weights of sub-indexes have not impact on scores of pillars and sub-indexes that are formed by number of indicators.

The EU economies are placed in three clusters: the overwhelming part in the clusters of the most productive and competitive countries that have already transformed or being in transition to innovative economy; only Bulgaria and Romania are placed in the efficient-driven cluster as economies that are on the way to innovative economy. Also the "Europe 2020 Strategy" (EC, 2010a) envisages a central strategic role of a complex innovation process: "… Europe's competitiveness, our capacity to create millions of new jobs to replace those lost in the crisis and, overall, our future standard of living depends on our ability to drive innovation in products, services, business and social processes and models" (EC, 2010b).

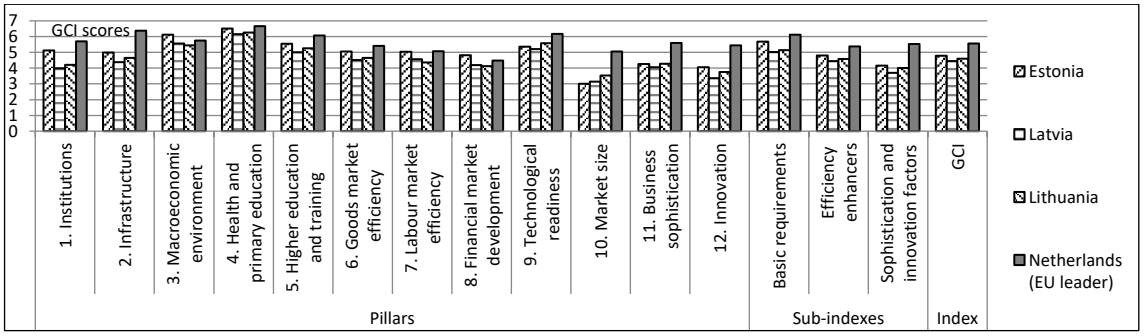

Figure 6. The GCI 2016/17: scores of the Baltic States

Source: GCI 2016/17

Therefore the innovation related pillars are analysed in more detail. The GCI provides two options:

1. 12th pillar focuses on creative issues – human resource, capacity and collaboration of research and business, investments in R&D, intellectual property. Its correlation with the GDP pc has increased till 0.93.
2. 3rd sub-index connects creative activities with technology transfer and industry, its willingness to new products and capacity for commercialization, clusters, presence and interaction in the value chain, technological and management level (11th pillar). The sub-index shows capacity of the economy to achieve the economic benefits (growth of GDP) from innovation; it is quite naturally that its correlation with the GDP pc is even higher – 0.95 (fig. 5b).

In total it suggests a thesis on innovation as the real basic driving force for the EU economies and outlines our next step – switch to innovation-driven indexes.

4. INNOVATION-DRIVEN INDEXES

There are two innovation-driven indexes, which rank the EU economies – the Global Innovation Index (GII) and the European Innovation Scoreboard (EIS).

Global Innovation Index – a step towards innovation-related evaluation

The GII is integrated from 82 indicators; the edition 2016 covers 128 countries. Functionally it is a shortened version of the GCI that is more focused on innovation process and activities; detailed information on macroeconomic environment and markets is not included. In addition number of positions directly uses the GCI data (including subjective viewpoints too). Due to increased specific impact of innovation related indicators, the compliance of the GII with GDP pc for EU countries (evaluations of 25 of them are in the top third of GII scores) is stronger in comparison with the GCI (Table 1); it directly confirms that we are on the right way.

Table 1

Correlations of various indexes/models with GDP pc (2015)

Index, model	**Scope of indicators**	**Correlation of fitted values with GDP pc**
GCI, 2016	Comprehensive, multi-sectoral	0.88
12th pillar of GCI, 2016	Innovation, soft	0.93
3rd sub-index of GCI, 2016	Innovation + business sophistication	0.95
GII, 2016	GCI - macroeconomics, markets	0.91
EIS, 2015	Innovation, hard, wide	0.95
27 indicators' model, 2015	Innovation + DESI, energy productivity	1.0
3 indicators' model, 2015	Top publ., PCT patents appl., energy prod.	0.9867
Joint model, 2008-2015	Top publ., PCT patents appl., energy prod.	0.9646

Developed by authors

At the same time the correlation of the GII is lower than that of GCI 12th innovation pillar. Actually the data scope of the GII should be considered as preserving support of the global index for less innovative factor-driven countries. Serious doubts arise on usefulness to include remaining non-innovation characteristics (government effectiveness and infrastructure) in the evaluation of innovative EU economies.

European Innovation Scoreboard – an exit point for modelling

The European Innovation Scoreboard (EIS) produces a completely innovation-directed Innovation Performance Index (IPI) that is composed from 25 hard components. The index is totally oriented to EU growth strategy; no one alongside item is included, once again underlining that these indicators are not conclusive for the EU countries. The compliance with the GDP pc has achieved very strong level (fig. 7a); it exceeds that of 12th innovation pillar of the GCI, and completely confirms the strategic thesis on innovation at the heart of the "Europe 2020 strategy".

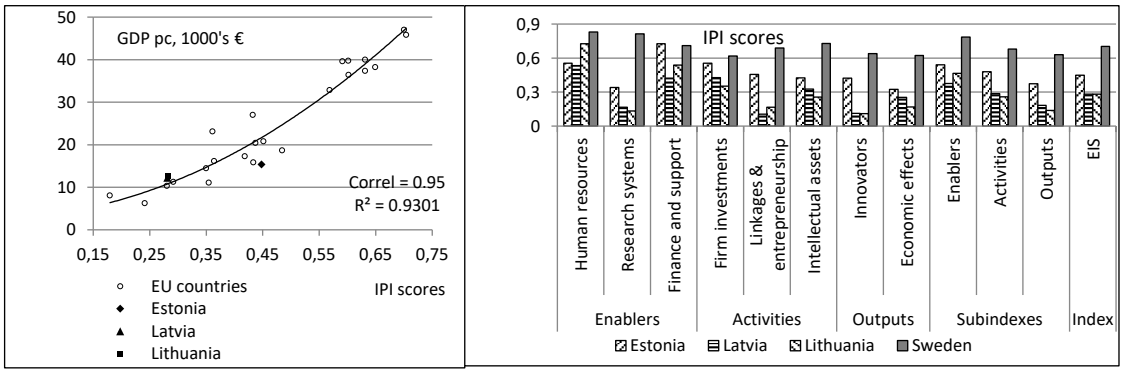

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Figure 7. EIS 2016: correlation of IPI with GDP pc, 2015 (7a) and IPI scores for the Baltic States (7b)

Source: EIS 2016

Unfortunately, the gap of the BS with the overall EU leader (Sweden) has significantly increased, because all softened dimensions are omitted. The EIS indicates weaknesses in the National Innovation Systems of BS (especially it relates to Latvia and Lithuania) – weak research system, unproductive its linkage with entrepreneurship and insufficient amount of innovators (fig. 7b); Estonian indicators are more balanced, its primacy on Baltic scale is evident. Nevertheless Estonians have classified insufficient capacity to innovate as very problematic factor, while the less successful Latvians and Lithuanians do not consider this issue as critical.

There is a very strong compliance of the IPI with economic development, consequently the data set of index can be used as a point of exit for further optimizations, i.e., for creation of the growth model. At the same time study of the composition of data set and methodology of IPI reveals two aspects for optimization activities.

The data set of the IPI reflects innovation oriented position, while the innovation is not a goal in itself. The target is growing GDP that results in higher quality of life; it is achievable increasing productivity by transforming economy to innovative products (increased value added) and processes (advancement) in high-tech as well as in traditional sectors. Therefore scores of the 3rd sub-index of the GCI as the composite output-oriented indicator (fig. 5b), better reflects the final results of valorisation of innovation process (*transformation of knowledge into money*); there is a positive impact from the inclusion of business sophistication indicators in the data set.

It was therefore sought an indicator that describes the structure of the economy, diffusion of innovation in the economic system, cleverness of business and the capacity of business entities to implement innovation-based activities. After evaluation of several hard indicators, two of them were chosen as the most promising.

The Digital Economy and Society Index (DESI) is a composite index (see DSM, 2017) that can serve as an indicator of transition of business transactions to the advanced digital environment; the last one is substantial for operative cooperation in creativity, for interactive processes both in the creation of knowledge and in its valorisation, for the development of products and efficient functioning of innovative business (clustering, remote cooperation, marketing, etc.). Composition of the DESI (penetration of and access to broadband, digital skills, business and public activity in use of digital services) reflects actually

implemented support, which enables various aspects of innovation, indirectly showing the level of knowledge-based activities and products.

The energy productivity is a statistical parameter, which formally shows amount of the GDP per unit of consumed energy. Actually it is not only the ecological indicator, as it is presented in the GII; it indirectly reflects the structure of national economy, level of transition from resource- and factor-driven priorities to advanced technologies and efficient processes, proportion of knowledge intensive products and processes, importance and usefulness of innovation process for the economy as a whole, readiness of business to implement this process.

The second aspect relates to the methodology of the IPI. There are equal specific weights of all 25 components in the scores. It is very doubtful that it would be an optimum balance. E.g., the secondary education cannot be evaluated as the asset for today, it is a basis for future activities. Therefore further modelling will be directed to finding optimum specific values for all components achieving the higher correlation with dependent indicator, which serves as the quality criterion of the model.

5. MODELLING

Thus we have 27 predictors and the GDP pc as the target/response variable for 26 EU economies. Direct usage of general linear regression multi-variable modelling means, that we are searching the 27-dimension hyperplane on which 26 defined points are placed (see table 1). Mathematically it is possible in any case, so we can obtain an ideal formal coincidence (correl = 1, $R^2 = 1$).

The problem is a lot of negative value coefficients for predictors in the outcome to achieve the ideal correlation; this situation contradicts the logics and practice. Any model cannot be an abstract representation of some data scope. "No model can include all of real world's complexity or the nuance of human communication… Models are constructed not just from data but from the choices we make about which data to pay attention to – and which to leave out. They must deliver transparency, disclosing the input data they're using as well as the results of their targeting" (O'Neil, 2016).

The impact of various predictors on the GDP pc really is different, very diverse correlations is convincing evidence. E.g., the medium and high-tech product exports as % of total product exports actually is not a decisive factor for the GDP growth, because the share of traditional sectors and products remains significant for any economy; at the same time everyday improvements in performance of processes and quality of products are with crucial importance. In addition there is a strong mutual correlation between several predictors (e.g., between scientific publications among the top 10% most cited publications and international scientific co-publications); algorithm of the regression choose the more significant in current position.

Therefore the WEKA data mining package (Witten et al, 2011), which contains several built-in smoothed linear algorithms, was chosen for development of the growth model. Reduction of information noise and exclusion of overfitting is its crucial advantage; in our case it sift out the less substantial predictors and created searched regularities on the basis of the major ones. Two used algorithms (M5P and M5Rules) provided slightly different pruned outcomes with persistently excellent correlation (0.9893 and 0.9882 correspondingly). The sets of used predictors and their specific weights are slightly different, but in total only six of them reflect the relevance and determine the smoothed models: new doctorate graduates, international scientific co-publications, scientific publications among the top 10% most cited ones, PCT patents applications, business R&D expenditure, energy productivity.

In addition during the modelling process the WEKA proposed grouping economies in two clusters by minimum angles between countries' GDP pc vectors in multidimensional (formed by predictors) space.

Two a little different model rules is the outcome of each algorithm; this issue significantly complicate the models. A remarkable issue: division of economies, which is determined by the most significant predictors, fully coincides with divided "two-speed Europe" that was recognized in fig. 5.

For further optimization of model after the determination of significand predictors, we choose the well-developed, powerful and at the same time user-friendly R statistics language. In difference with the WEKA package, R as a programming language provides more flexible algorithms for modelling. Looking through options, we found that by insignificant reduction of correlation it becomes possible to create a single regularity for all EU economies (fig. 8a), which is based on three predictors only (table 1):

– scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country;

– PCT patents applications per billion GDP (in PPS €);

– energy productivity, produced GDP (€) on a gross inland consumed energy (kG of oil equivalent).

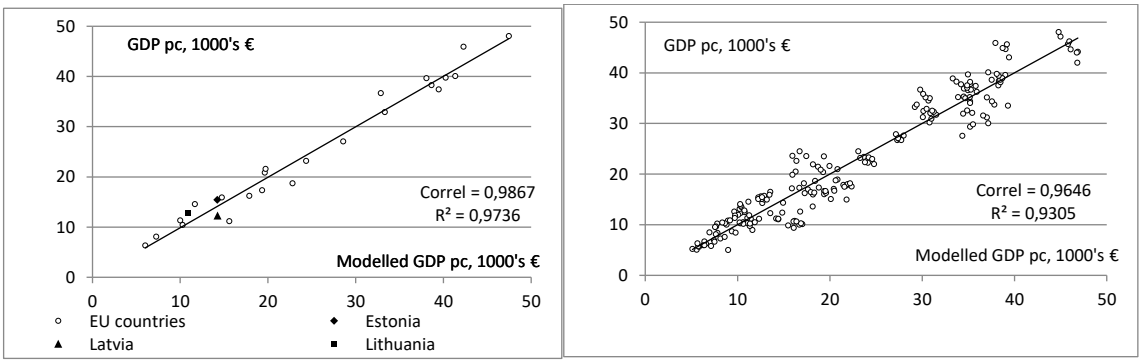

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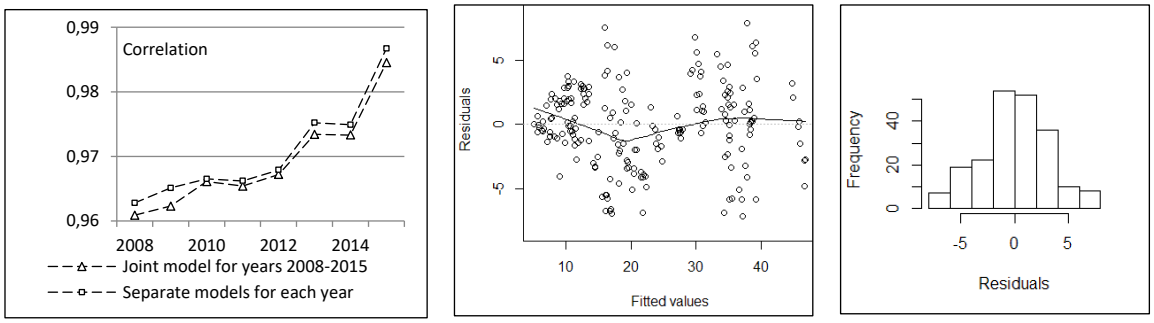
Figure 8. Coincidence of the 3-indicators models for 2015 (8a) and for 2008-2015 (8b) with real GDP pc

Developed by authors

Such a simple model for complicated issue asks for many-sided its testing. Therefore a joint regularity for years 2008-2015 (EIS time coverage) was created (fig. 8b); a general correlation of modelled values with real GDP pc is excellent (table 1), especially taking into account that it is a complicated period, which includes years of hard economic crisis, post-crisis recovery and return to the sustainable growth. Calculations, which were made for each year using the created joint regularity, show a gradual increasing of correlation (fig. 9a); it reflects on one hand the sustainability of both EU innovation-driven economic policy and our model as well as an increasing convergence of the EU economics on the innovation-driven growth strategy.

The number of dependent variables of the joint regularity is sufficiently large to evaluate residuals. Fig. 9b shows that there is no general dependency between the residuals and fitted values, thus the model is independent in relation to the GDP pc values in the whole their scale. Nevertheless one can indicate the trace of two-speed Europe; the absolute growth rates of countries in various clusters are too different. Histogram 9c indicates the distribution of the residuals that is very near to normal; the fitted values are non-biased. The p-value is < 2.2E-16.



a) b) c)

Figure 9. Correlations of fitted models 2008-2015 (9a); residual characteristics of the fitted joint model (9b, 9c)

Developed by authors

A corresponding regularity was created for each year in the period 2008-2015. Quality of the models, of course, is a little bit higher in comparison with the joint regularity (fig 9a). The most hard test is a usage of regularity 2008 (hard crisis) for data 2014 (after-recovery growth). Achieved coincidence (Correl = 0.971, $R^2 = 0.9426$) approves the real possibility to exploit the model of current for next years' predictions and planning.

CONCLUSIONS

The created benchmarking model well reflects the growth of EU economies despite their diversity. It does not depend on the size of the economy, covering tenfold changing GDP pc; thus it would be used for sustainable planning and assessment of leading as well as catching economies. The model has been tested for 2008 – 2015, that is a period of hard economic crisis, post-crisis recovery and return to sustainable growth; there are very different preconditions for the progress in separate years of the period. Possibilities to use a single functional regularity for so diverse years, even to use the regularity of deep crisis year 2008 for growth year 2014 show the universality and sustainability of the model.

The performed analysis and the model show the transformation of EU economies and their gradual convergence on innovation-driven growth path. Not only the creativity and innovation performance is substantial for the implementation of such growth model; strengthening of business sophistication, willingness and capacity of industry to absorb smart processes and advanced products play a crucial role. High-tech and start-up is the bright illustration of the trend, nevertheless traditional sectors and big business largely determine the economic situation.

All these factors strongly relates to the BS, which are not very successful in economy transformation to innovative one. Estonians currently are the leaders among the BS; nevertheless a lot of works are before them too. Various surveys show the basic shortages – weak research system, unproductive its linkage with entrepreneurship, insufficient amount of innovators, low general business sophistication.

It has to be strongly mentioned that indicators, which are drivers of the model, is a peak of the pyramid. Actually the often cited publications and the PCT patents applications are the tops of various levels' publications and patents applications; their quantity reflects the performance and financing of education and R&D system, human resources, creative capacity of society and political demand for knowledge-based activities. The energy productivity well reflects the structure of economy, proportions of productive intellectual (creative) activities in various sectors and resource-based work.

The simplicity of proposed model is its strong advantage for the practical application to planning and/or prediction. Despite of the usage of three predictors only, the coincidence of model with real statistical GDP pc is extremely strong (correlation is between 0.961 – 0.987). In fact it is a bright illustration of Antoine de Saint-Exupery maxim: "Perfection is achieved not when there is nothing more to add, but when there is nothing left to take away".

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