Consistency between innovation indicators and national innovation performance in the case of small economies

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Abstract

The paper bridges two approaches to assess national innovation performance based on the European Innovation Scoreboard (EIS) composite indicators as well as on innovation indicators elaborated by us with implementing a factor analysis. The main focus of the study is on analysing the innovation performance in the case of Baltic countries – small economies, which have similar post-socialist path dependence. The paper aims to explore what factors have been the most influential in the innovation performance of these countries, and whether these are correctly captured by the EIS indicators. We conclude that EIS methodology based assessment results are robust and, as a rule, consistent with real innovation performance of the countries. The results of our study also show that some measuring problems may occur when elaborating composite indicators of national innovation performance, e.g. the inability to sufficiently capture the quality of human capital, small economy effect, i.e. high dependence on single enterprises of a sector, data availability issues, self-reporting problems, etc. A common problem for the Baltic States is the weak link between science and enterprises, which is also not fully captured by the EIS indicators.

Keywords: national innovation performance, innovation measurement, composite indicators, small economies

JEL classification: O3, O1, C8, I2

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1. Introduction

The concept of innovation and the methods for measuring it have been under constant dispute for decades. Innovation measurement has been developed together with the theories of innovation. They basically rely on science-push and market-driven innovation theories focusing also on the important role of knowledge, institutions and social networks. A broadly spread research branch is the one on national innovation systems (NIS) (Filipetti and Archibugi 2011; Fagerberg Srholec, M. 2008; Edquist and Hommen, 2008; Lundvall et al. 2002). However, the virtue of this research is that it is a thorough one which offers a representative picture of the different policies and institutions of a country. At the same time, this is a disadvantage for those who are not scholars and want to have a quick and comparative overview of innovation performances of different countries, i.e. policy-makers. Policy-makers prefer scoreboards or aggregated indicators, which capture different information and aggregate this into a single number or country ranking. Of course, the aggregation has also well-known disadvantages like variability of data quality, implementation of different aggregation methods, etc.

The main focus of this study is on analysing the innovation performance of the Baltic States – small countries, which have similar post-socialist path dependence; their economies are also comparable in size.[1] As Fagerberg and Srholec (2008) have pointed out, the difference in nature, geography and history influence the ability of a country to develop a well-functioning innovation system. In that sense, Baltic States are a particularly interesting case for studying innovation performance as well as the factors behind the differences between the countries. According to the European Innovation Survey 2008 (EIS 2008), Estonia belongs to the group of moderate innovators; the two other Baltic States, Latvia and Lithuania, belong to the group of catching-up innovators[2].

Our aim is to explore the extent to which factors have been most influential in the innovation performance of these countries, and whether the assessments of innovation performance that rely on implementation of several methodologies provide stable results. We believe that the results of our study will provide additional understanding for the development of innovation assessment methodologies taking into account the size and path dependence of an economy. The overwhelming aim of the study is to generate additional

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[1] The population of Estonia is only 1.3 million, of Latvia 2.2 and Lithuania 3.3 million. The GDP pc formed about 70% of the EU average in Estonia, 54% in Latvia and 58% in Lithuania in 2010.

[2] In 2009 Estonia improved her position belonging now to the group of countries that are innovation followers (EIS 2008 and EIS 2010). Other two countries Latvia and Lithuania are still catching-up innovators (EIS 2010); Lithuania was ranked to the moderate innovators in 2009.

information for elaborating policy proposals and for making decisions that support the development of national innovation performance.

We analyse data from several sources to give a snapshot of different aspects of innovation, like the European Innovation Scoreboard (EIS) methodology does. We elaborate our own methodological approach that is based on the implementation of the principal component factor analysis and compare the analysis results with EIS. First, we try to find out whether the assessment results and rankings of the countries according to their national innovation performance based on different methodological approaches are robust or not. Second, we examine how sensitive the national composite indicators are to the changes of a single initial innovation indicator. In our analysis we mainly rely on the data until 2008; the period before the tremendous consequences of the global economic crisis.

This paper is structured as follows. In the following part we give a short overview of the theoretical and methodological framework for analysing national innovation performance. The next parts of the paper present the results of the comparative analysis of innovation performance in the Baltic States relying on two methodological approaches – a comparative analysis based on EIS and a factor analysis as a multivariate analysis technique. The paper ends with conclusions and discussion.

2. Theoretical and methodological framework for assessing national innovation performance

The literature on innovation and its measurement has evolved with an understanding of the innovation process (Rodriguez-Pose and Crescenzi, 2008; Landry et al., 2002; Marinova and Phillimore, 2003). In general, we can observe that the majority of approaches focused on understanding the essence of an innovation process started with science-pushed and market-driven innovation theories and followed with innovation theories that imply that innovation is knowledge-based, but also very dependent on social networks. Another direction in the development of innovation literature belongs to a deeper consideration of the viewpoint that a firm does not innovate in isolation, but depends on extensive interaction with its environment (e.g. open innovation; see Chesbrough 2003; Chesbrough et al., 2009).

Various concepts have been introduced to enhance the understanding of this phenomenon, most of them including the terms "system" and "national innovation systems" (NIS) (e.g. see Lundvall et al., 2002; Fagerberg, 2005; Edquist and Hommen 2008; Filipetti and Archibugi, 2011). The research based on the NIS concept is mostly a qualitative analysis of a selected country's innovation system. The NIS concept has initially been applied to developed European countries (Lundvall et al., 2002). Lately, it has also been applied to less developed countries. For example, recent analyses of innovation show that countries are divided in two categories: rapid growth countries (Taiwan, Singapore, Korea, Ireland and Hong Kong) and slow growth countries (Sweden, Norway, the Netherlands, Finland and Denmark) (see Edquist and Hommen, 2008).

The development of innovation theories had already called for the need to develop methods for measuring innovation in the 1980s (see Arundel et al., 2008). Up until the 1980s, innovation research was largely limited to case studies or to data on the creation of new knowledge, as measured by R&D investments, scientific publications, patented inventions and the stock of scientists and engineers. Arising from that, the traditional indicators used for innovation analysis were R&D expenditures, data on patent applications and bibliometric data. However, there are also several problems arising from the use of such innovation indicators (see also Smith 2005). Ordinarily these indicators reveal only one or some aspects of innovation performance; sometimes they reveal only the preconditions for innovation and do not have direct links to the economic outcomes. The NIS based approach to studying innovation performance does not provide sufficient information for the comparative analysis of national innovation performance.

Stemming from the need for comprehensive information about innovation, different surveys regarding innovation were started at the end of the 1980s and the beginning of the 1990s. According to Smith (2005), innovation surveys can be divided into two basic types: object approach and subject approach surveys. The object approach focuses on the innovation itself and records information on the output of the innovation process. Information is collected from new product announcements, expert surveys, innovation inventories, and so on. The most important example of the object approach is the SPRU database, developed by the Science Policy Research Unit at the University of Sussex. However, innovation activities must be innovative enough to be publicized published in trade journals or the general press; this requirement may cause a sample selection bias (Archibugi and Sirilli, 2001). The subject approach focuses on the innovating firm and records information on the input to the innovation process. The information is collected at the firm level by using mail questionnaires or direct interviews. The most important example of the subject approach is the Community Innovation Survey (CIS). While object approach surveys can be accused of innovations having to pass a test of significance, the opposite criticism – subjectivism – holds for subject surveys like the CIS (IAREG, 2008).

There is a certain constant need for the comparative assessment of the national innovation performance; for example, policy-makers and sometimes also foreign investors prefer short and quick overviews of cross-country innovation performance, like innovation scoreboards. Therefore, different composite indicators are being elaborated by several international organisations and associations, such as the World Bank, UN institutions, the World Economic

Forum and the Economic Commission. Innovation scoreboards can mainly serve three policy needs (see also Arundel and Hollanders, 2008). First, they act as an 'early warning' system for potential problems at the national level. Second, if used over time, they can track changes in national strengths and weaknesses. And third, they can attract the interest of policy-makers, civil servants and elected officials, and investors. In reality, mass media and politicians use these composite indicators intensively in their activities.

In Europe, the most widely known set of composite innovation indicators is the European Innovation Scoreboard (EIS). Of course, there are also several problems related to these composite indicators and these are widely discussed in the literature. For example, Grupp and Schubert (2010) have criticized the weighting system in the EIS and find that the Summary Innovation Index is extremely non-robust to changes in weights. Schibany and Streicher (2008) bring out several problems in the EIS such as the selection of indicators, the mixture of short-term and long-term indicators, multicollinearity, "the more, the better" assumption, outliers, statistical issues and comparability.

Regardless of the several discussions and arguments presented in the innovation literature, we consider that composite indicators are still feasible and practical tools for measuring and analysing such complex phenomena as innovation at least at the national level. We find that the EIS is an appropriate methodology that fits the aim of our study and allows us to analyse the innovation performance of the small countries like the Baltic States in the context of other European countries. In order to check the robustness of the assessment results, we also elaborate our own methodological approach which bases on the implementation of a factor analysis as a multivariate analysis technique and interlinks innovation input, output and processes indicators.

3. European Innovation Scoreboard methodology for assessing national innovation performance

In order to analyse the innovation performance of the Baltic States as small economies in the context of other European countries, we use EIS data and methodology, published annually since 2001, to track and benchmark the relative innovation performance of the EU member states (Inno-metrics, 2009). Up until 2007, the indicators were grouped into two main categories: inputs and outputs. The methodology was revised for EIS 2008, and there are three main categories of indicators:

1) "Enablers" capturing the main drivers of innovation that are external to the firm: "Human resources" and "Finance and support";
2) "Firm activities" captures innovation efforts that firms undertake, comprising "Firm investments", "Linkages & entrepreneurship" and "Throughputs";

3) "Outputs" capture "Innovators" – the number of firms that have introduced innovations onto the market and within their organisations; and "Economic effects".

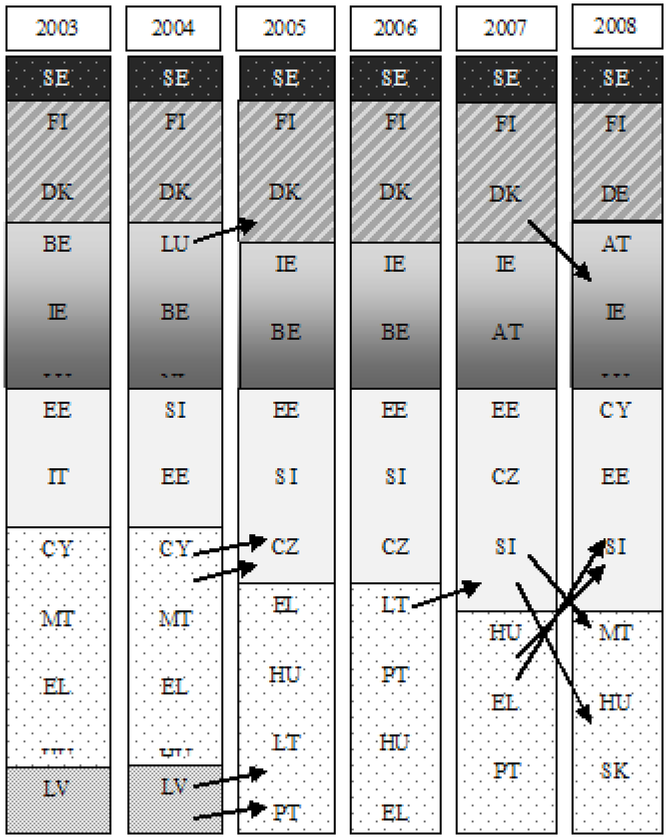
Altogether there are 29 initial innovation indicators covered by EIS 2008; more than half of them (16) are based on the Eurostat databases. A remarkable number of indicators (8) are derived from the Community Innovation Survey (CIS). Other data sources are IMF, World Bank, Office of Harmonization for the Internal Market and Thomson/ISI.

According to the EIS evaluations, the EU member states are divided into four country groups: 1) innovation leaders, 2) innovation followers, 3) moderate innovators, and 4) catching-up countries (figure 1). These country groups have been formed according to the Summary Innovation Index (SII), which is calculated as a composite of the initial statistical indicators. The countries with an innovation performance above the EU27 average are the innovation leaders and followers. Those countries whose innovation performance is below the EU27 average are moderate innovators and catching-up countries. According to the EIS-2008, Estonia belongs to the moderate innovators group; Latvia and Lithuania are somewhat behind, belonging to the group of catching-up countries.

The EIS based classification of the countries according to their innovation performance has been rather stable for the period under observation (figure 1). Only some countries have changed their positions between the groups and these as a rule are small economies. Luxembourg changed its position twice: in 2004–2005 (moving from the group of innovation followers to the group of innovation leaders) and in 2007–2008 (moving from the group of innovation leaders again back to the group of innovation followers). Cyprus and Malta improved their innovative position in 2004–2005 thus moving from the group of catching-up countries to the group of moderate innovators, but Malta fell back into the catching-up group in 2007–2008. Similar dynamics can be witnessed in the case of Lithuania, which moved from the group of catching-up countries to the group of moderate innovators in 2006–2007 and fell back into the group of catching-up countries in 2007–2008. Greece and Portugal improved their innovative position in 2007–2008, belonging to the group of moderate innovators in 2008. We can see more changes in the assessment results for the years 2005 and 2008, when the EIS methodology was remarkably developed.

The movements of the countries between the EIS based classification groups confirm our opinion that, despite the fact that the EIS results are rather robust, the innovation measurement results are still sensitive to the assessment methodology and the indicators selected as well as to several other measurement problems that EIS has been criticized for (see for example Schibany and Streicher 2009). Small countries are particularly sensitive to these innovation measurement problems. As it can be seen in Figure 1, the recent developments in the EIS methodology of 2008 were first of all reflected in the evaluation results of the national innovation performance for small (Malta, Lithuania) and southern European countries (Portugal, Greece). The overall assessment results are rather stable, indicating that the EIS methodology generally provides robust results that are consistent with the real innovation performance of the countries.

Figure 1. Country groups according to EIS for 2003–2008



Source: Inno-metrics 2008 & 2009[3]

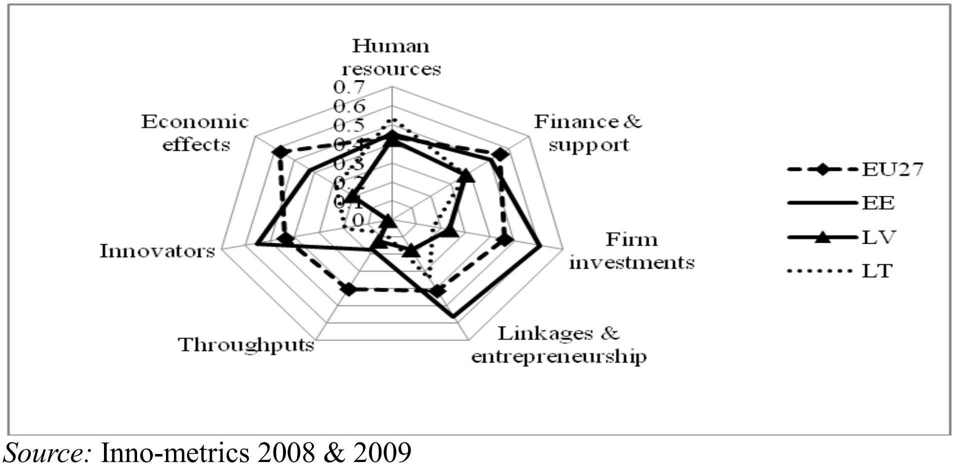
[3] Country abbreviations: AT – Austria, BE- Belgium, BG – Bulgaria, CH – Switzerland, CY – Cyprus, CZ – Czech Republic, DE – Germany, DK – Denmark, EE – Estonia, ES – Spain, FI – Finland, FR – France, GR – Greece, HR –Croatia, HU – Hungary, IE – Ireland, IS – Iceland, IT – Italy, LT – Lithuania, LU – Luxembourg, LV – Latvia, MT – Malta, NL – Netherlands, NO – Norway, PL – Poland, PT – Portugal, RO – Romania, SE – Sweden, SI – Slovenia, SK – Slovakia, TR – Turkey, UK – United Kingdom

The changes in the choice of initial indicators and the improvements to the EIS methodology reflect changes in the understanding of the innovation process and the development of innovation models. The majority of the EIS indicators are still better suited to capturing science-based innovation; only some improvements made in EIS-2008 capture indicators that reflect the core ideas of the user and open innovation models. Thus, the development of the EIS methodology represents natural progress, being in accordance with the three reasons for the measurement of innovation and comparative assessment of national innovation performance mentioned as important in the first part of this paper.

Analysing the innovation performance of the Baltic States we first of all focus on examining the EIS Summary Innovation Index. The Summary Innovation Index reflects the following six dimensions of national innovation performance: 1) human resources; 2) finance & support; 3) firm investments; 4) linkages & entrepreneurship; 5) throughputs; 6) innovators; and 7) economic effects.

In figure 2, the Summary Innovation Index of the EIS is presented for the Baltic States and the EU27 average.

Figure 2. The Summary Innovation Index using dimensions of the European Innovation Scoreboard for the Baltic States and EU27 average in 2008 (composed by the authors based on EIS 2008; see also Paas and Poltimäe 2011).



Source: Inno-metrics 2008 & 2009

Two of the dimensions presented in figure 2 (human resources and finance & support) capture the main drivers of innovation that are external to firms in the Baltic States belonging to the group of innovation indicators called “Enablers” and representing first of all the preconditions for innovation (inputs).

The next three groups of indicators (firm investments, linkages & entrepreneurship and throughputs) capture the innovation efforts that the firms undertake, and they belong to the category of innovation indicators called “Firm activities”. This group of indicators reflect possible activities that the firms pursue in order to transform innovation inputs into outputs. The last two groups of indicators (innovators and economic effects) belong to the category of indicators called “Outputs”, and they reflect the outputs of the innovation activities. The group of indicators called “Innovators” represent the number of firms that have introduced innovations onto the market, and the group of indicators called “Economic effects” represent the factors that are external to the firms.

Based on the EIS methodology assessment results we can conclude that although one aspect of the innovation input – human resources – is at a comparatively good level in the Baltic States, the transformation process into innovation output has been more successful in Estonia than in Latvia and Lithuania. Estonia is doing better than the EU27 average in several categories, such as human resources, firm investments, linkages & entrepreneurship and innovators. At the same time, Estonia is lagging behind in economic effects and especially in throughputs. Lithuania is doing comparatively well in human resources and linkages & entrepreneurship, but lagging behind in the other dimensions. Latvia’s innovation performance is the lowest among the Baltic States. Regardless of the good performance in human resources, the performance in other dimensions is low. The common problems for the Baltic States are the weak links between human resources and economic effects of innovation as well as between science and enterprises. These links are not fully precisely captured by the EIS indicators.

4. Factor analysis for elaborating composite indicators for assessment of national innovation performance

In order to analyse the robustness of EIS results we implement a factor analysis for elaborating additional composite indicators of the national innovation performance. The high interdependence of the initial innovation indicators (called multicollinearity) is one of the problems related to the measurement of innovation that was also stressed by Schibany and Streicher (2008). The implementation of factor analysis enables us to avoid this measurement problem.

The factor analysis (FA) aims to describe a set of initial k variables $X1, X2, \ldots Xk$ in terms of a smaller number of m factors thus highlighting the relationship between these variables (for more see Nardo, et al., 2005).

The factor model is as follows:

$$X_i = \sum_{j=1}^{m} a_{ij} F_j + e_i \qquad (1),$$

Where
$X1, X2,\dots Xk$ – initial variables (standardised with zero mean and unit variance);
$i = 1,2,\dots k$; k is the number of the initial variables;
$F1, F2, \dots Fm$ – aggregated indicators – common factors (uncorrelated, each has a zero mean and unit variance); $j = 1, 2,\dots m$; m is the number of factors;
aij – factor loadings related to the variable Xi, measured as a correlation between the initial variable i and factor j;
ei – the specific factor supposed independently and identically distributed with zero mean.

There are several approaches to dealing with model (1), for example, the centroid method, the principal axis method and the principal component factor analysis (for more see Nicoletti et al., 2000). The most common approach, which is implemented by elaborating composite indicators, is to extract the first *m* principal components and consider them as factors and neglect the remaining information.

The interpretation of the essence of the aggregated indicators (or factors) is based on the matrix of the factor loadings *(aij)*. In order to support the interpretation of the factor loadings and to obtain a clear pattern of factor loadings, the rotated matrix of the loading is often calculated. There are various rotation strategies that have been proposed. The most common rotation method is the "varimax rotation", which is used also in our case.

To sum up, the main steps for elaborating the composite indictors implementing factor analysis for assessing national innovation performance are as follows:

1) Choose the initial statistical indicators that describe several aspects of innovation performance: innovation inputs, innovation outputs and processes allowing the transformation of inputs into outputs.
2) Calculate the covariance/correlation matrix for the initial indicators.
3) If possible, identify the number factors necessary to represent the initial indicators (based on theoretical considerations) and the method for calculating them.
4) If necessary, rotate the factors to enhance their interpretability.
5) Interpret the essence of the composite indicators of the innovation performance.
6) Calculate factor scores for the composite indicators and elaborate country rankings according to their innovation performance.

In order to elaborate new composite indicators for the national innovation performance implementing factor analysis we mainly relied on the Eurostat and Inno-metrics database of the EIS. The database includes statistical indicators that describe several aspects of innovation performance for the EU27 countries, including data for five non-EU countries: Croatia (HR), Turkey (TR), Iceland (IC), Norway (NO) and Switzerland (CH). The initial indicators we chose for the assessment of the innovation performance belong to three groups which should be able to represent the main characteristics of the EIS categories: innovation enablers, firm activities and outputs. The final choice of the initial indicators for our analysis bases on several theoretical, empirical and methodological considerations as well as on checking of the robustness of the extraction results (based on Cronbach coefficients, several statistical tests and the correlation matrix). Based on these considerations as well as on the test results, the indicators were chosen so as to reflect the internal consistency of the initial items and describe the national innovation performance from different angles: innovation inputs, activities and outputs.

We are aware of the fact that the factor analysis implementation always contains some subjectivity in the sense of choosing the set of initial indication, extraction and rotation methods as well as of interpretation of the estimation results. We try to mitigate this subjectivity checking for the robustness of the results by using different sets of initial indicators and implementing several methodological approaches.

Based on all these considerations, the chosen set of initial variables for implementing the factor analysis consists in the following indicators:

- people with tertiary education per 100 population aged 25-64 (TERTIARY);
- participation in lifelong learning per 100 population aged 25-64 (LIFELONG);
- public R&D expenditure as % of GDP (PUBLIC_R&D);
- business R&D expenditure as % of GDP (BUSINESS_R&D);
- public-private co-publications per million population (CO_PUBLICATIONS);
- EPO patents per million population (PATENTS);
- Non-R&D innovation expenditure as % of turnover (NON_R%D_INNO);
- SMEs introducing product or process innovations as % of all SMEs (PROD_PROC_INNO);
- SMEs introducing marketing or organisational innovations as % of all SMEs (MARKET_INNO);
- employment in medium-high and high-tech manufacturing as % of workers (TECH_EMPL);
- medium and high-tech manufacturing exports as % of total exports (TECH_EXPORT).

Appendix 1 presents the correlation matrix of the selected innovation indicators. We can see that the majority of the initial innovation indicators are significantly correlated. Only the non-R&D innovation expenditure indicator does not have a statistically significant correlation with the other indicators. Thus, we will exclude this indicator by conducting a factor analysis and elaborating new aggregated indicators of the countries' innovation performance. In the next part of the paper we rely on this correlation matrix to extract the aggregated indicators – factors which, in our case, can be considered as the composite indicators that describe different aspects of national innovation performance of the European countries.

5. Empirical results of implementation of factor analysis

5.1. Aggregated indicators of countries' innovation performance

Based on the selected set of initial innovation indicators for the 32 countries included in EIS (see part 4), and using the principal components factor analysis method, we extracted three principal components – factors *Fj (j=1,2,3)* that explains 81.3% of the variation of the initial indicators. The first factor (F1) explains 37.3%, the second (F2) 22.9 % and the third (F3) 21.0% of the total variation. Table 1 presents the rotated factor loadings for these factors – innovation components, and the explained variance.

Factor F1 has the strongest loadings (correlations) with the indicators LIFELONG (0.904), CO_PUBLICATIONS (0.885), PUBLIC_R&D (0.823), PATENTS (0.746), and BUSINESS_R&D (0.742). All these indicators reflect first of all the preconditions for innovation activities including human resources (characterised by education), their activities (patents, publications) and both private and business R&D expenditure. Thus, we name this factor the innovation input component (F1), which consists of indicators of both groups "Enablers" and "Firm activities", indicating that these groups of initial indicators used by the EIS approach (see part 3) are strongly interlinked.

Factor F2 has the strongest loadings with the variables PROD_PROC_INNO and MARKET_INNO. We interpret this factor as the innovation pursuit component (F2) indicating innovation activities of the countries.

Factor F3 has the strongest loadings with the important outcomes of the innovation process, the variables TECH_EMPL and TECH_EXPORT, which reflect the share of employment in the technology oriented sectors and the export of technological production in total exports. This factor can be interpreted as the innovation output component.

At the first glance, it is somewhat surprising that in the case of F3 there is a strong negative factor loading with the variable TERTIARY (-0.665). But we suppose that it is consistent with the correlation analysis results (see appendix 1) and the initial innovation indicators of the countries. The share of people with tertiary education is as a rule rather high in the EU new member states – the Central and Eastern European countries. At the same time, the innovation outcome expressed by the employment in medium-high and high-tech manufacturing (TECH_EMPL) and the medium and high-tech manufacturing exports (TECH_EXPORT) are still low in these countries.

Table1. Rotated factor loadings

Initial indicators	F1 - INNOVATION INPUT	F2 - INNOVATION PURSUIT	F3 - INNOVATION OUTPUT
TERTIARY	0.530	-0.021	**-0.665**
LIFELONG	**0.904**	-0.166	-0.166
PUBLIC_R&D	**0.823**	0.176	0.013
BUSINESS_R&D	**0.742**	0.528	0.225
CO_PUBLICATIONS	**0.885**	0.198	0.006
PATENTS	**0.746**	0.446	0.056
PROD_PROC_INNO	0.201	**0.913**	-0127
MARKET_INNO	0.093	**0.928**	-0.112
TECH_EMPL	0.096	-0.060	**0.902**
TECH_EXPORT	0.063	-0.128	**0.855**
Explained variance, %	37.263	22.925	20.983
Cumulative, %	**37.263**	**60.187**	**81.171**

Source: authors' calculations based on the Eurostat and Inno-metrics data of the period 2002-2008 for 32 European countries

Also, a recent analysis carried out by Filipetti and Archibugi (2011) showed that although qualified human resources play a crucial role in reducing the effects of crisis, this has not been the case in post-socialist countries, and apparently, the high level of human resources in the previously planned economies have not yet been fully incorporated into the new competitive economy.

Appendix 2 presents the factor scores of components F1, F2 and F3 as standardised indicators reflecting the level of the component for a country in comparison with other countries. If the value of the score is 0, it means that according to this component this country has the average level, and respectively a negative and positive score reflects the countries' position below or above the average.

In order to summarize the scores of the countries' innovation performance components F1, F2 and F3 to obtain an aggregated innovation indicator – the composite innovation indicator – we use the weights that represent the explanatory power of these components (see table 1). Thus, the weights are 0.373, 0.229 and 0.210.

To compare the rankings for the factor analysis based composite indicator with the EIS-2008 rankings, we rescale the EIS ranking by using the formula:

$$EIS_{rescale,i} = \frac{(X_i - EIS_{\min})}{(EIS_{\max} - EIS_{\min})} \qquad (2),$$

Where X_i represents the level of the EIS composite indicator for the country i ($i=1,2,...N$) and $EIS_{\min}$ and $EIS_{\max}$ are the minimum and maximum values for the respective EIS indicators.

The re-scaled indicators have the same dimension as the factor analysis and its score-based rankings: 0 – the country's innovation performance is on the average level; negative or positive re-scaled EIS composite indicators show that the innovation performance is below or above the average level (see appendix 2). The correlation coefficient between the two rankings is high (above 0.9) indicating that EIS composite indicators and respective rankings are robust also in the sense of other methodologies used for the comparative assessment of the national innovation performance. Thus, we can conclude that the EIS methodology based assessment results are reliable and consistent with real innovation performance of the countries.

5.2. Sensitivity of innovation measurement results to self-reporting

We also use the factor analysis methodology for examining our proposition that the initial innovation indicators, and thus the assessment results of the national innovation performance, may be sensitive to self-reporting, particularly in the case of small countries. Therefore, we additionally include in our set of initial innovation indicators the variable NON_R&D_INNO – the non-R&D innovation expenditure as % of turnover, and estimate again the factor model 1. This indicator is based on the CIS (Community Innovation Survey) and therefore reflects self-reporting activities and can be used as one possible proxy for self-reporting.

The results of implementing factor analysis are robust allowing us to extract the same three components: innovation input (F1), innovation activities (F2) and innovation output (F3). Table 2 presents the assessment results for national innovation performance in the Baltic States based on the composite indicators elaborated by using the factor analysis compared with the EIS-2008 composite indicators. The factor analysis based composite indicators consist of two variants: variant 1 based on 10 initial variables and variant 2 based on 11 initial variables including also the variable NON_R&D_INNO, which is considered a possible self-reporting proxy.

Thus, both the factor scores and the ranking of the countries are normally robust, but some differences may first of all exist in the case of small economies like Estonia, a small Baltic country (see table 2 and appendix 3). Small economies are more sensitive to possible self-reporting bias than larger economies are.

Table 2. Factor scores and composite indicators for the assessment of national innovation performance in the Baltic States, 2008

Country	Composite indicators based on weighted scores. variant 1	Composite indicators based on weighted scores. variant 2	EIS-2008	EIS-2008. re-scaled
EE	-0.201	-0.006	0.454	-0.026
LV	-0.654	-0.670	0.239	-0.241
LT	-0.664	-0.674	0.294	-0.186

Source: authors' calculations based on Eurostat and Inno-metrics data

Estonian innovation performance is evaluated remarkably highly when non-R&D expenditure is taken into account. The results of the other two Baltic States are rather stable. Thus, we can conclude that there are some self-reporting problems within the CIS regarding non-R&D expenditure in the case of Estonia. Taking into account that Estonian tax policy favours investments instead of paying dividends, our calculations confirm the argumentation that some aspects of tax policy in combination with self-reporting may be reflected in the assessment of national innovation performance. This reflection is particularly evident in the case of a small economy.

6. Conclusions and discussion

The paper bridges two approaches to the assessment of national innovation performance based on the composite indicators of the European Innovation Scoreboard (EIS) and on the aggregated innovation indicators elaborated by implementing the principal component factor analysis. The main focus of the study is on the analysis of innovation performance in the Baltic States – Estonia, Latvia and Lithuania – which are small EU economies with common post-socialist path dependence. We used factor analysis in order to elaborate alternative composite indicators to assess national innovation performance and to test the consistency of the EIS methodology and our assessment results.

According to the EIS assessments, the EU member states are divided into four country groups: 1) innovation leaders, 2) innovation followers, 3) moderate innovators, and 4) catching-up countries. Countries with innovation performance above the EU27 average are in the innovation leaders and followers groups, and those with innovation performance below the EU27 average are in the moderate innovators and catching-up countries groups.

According to EIS 2008, Estonia belongs to the third and the two other Baltic States, Latvia and Lithuania, to the fourth group. Also, the factor analysis assessment results are in accordance with this ranking. The EIS based classification of countries has been robust in 2003–2008; only a couple of countries have changed groups. Recent developments in the EIS methodology in 2008 are reflected first of all in the assessment results for national innovation performance in the small countries (EU new member states Malta and Lithuania and the Southern European countries Portugal and Greece). These reflections confirm our opinion that innovation measurement results are still rather sensitive to assessment methodology and the indicators selected to measure national innovation performance. Innovation performance is highly dependent on available data.

The results of our analysis show that some measuring problems may occur by elaborating composite indicators of the national innovation performance e.g. the inability to sufficiently capture the quality of human capital, the small economy effect, i.e. high dependence on single enterprises of a sector, data availability issues etc. The measurement results may also be biased by some self-reporting indicators. This opinion is confirmed by the comparison between the EIS evaluations and our assessment results based on the implementation of factor analysis. We compared the EIS and the factor analysis results and obtained confirmation that the composite results for small countries, particularly for Estonia, are sensitive to the self-reporting indicator of the CIS that reflects the role of non-R&D innovations in the national innovation performance.

Our research results show that the level of human resources is quite high and similar in the Baltic countries, which gives a good starting platform for innovation in these countries. However, the firms' innovation activities obtain considerably better results in Estonia than in Latvia and Lithuania. This tells us that the innovation processes do not depend only on the high level of human resources, but also on other enabling factors, which are influenced by different national policies. We suppose that Estonian better performance is connected to the tax policy and the origin of the foreign direct investments from the innovative Nordic countries like Sweden and Finland. At the same time, our results also show that the self-perception about innovation might be too high in Estonia.

Regarding EIS the problems we would like to turn attention to two main issues. First, the small economy effect on the indicators: small economies are highly dependent on single enterprises in one sector and therefore some indicators are very volatile. Secondly, the indicators on human resources often capture only some aspects of the education system, not the whole picture. The common problem for the Baltic States as small economies is the weak link between science and enterprises, which is not fully captured by the EIS indicators. In the further development of our research we are going to follow a widespread belief that innovation is a necessary assumption for a country's economic growth and we will focus on examining the relationship between economic growth and innovation indicators.

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Appendix 1. Correlation matrix of the initial innovation indicators for the EU and selected European countries, 2008

Indicat.	TERT	LIFEL	PUBRD	BUSRD	PUBL	PAT	NON	PROD	MARK	TECH_ EMPL	TECH_ EXP
TERT	1.000	.571**	405*	.417*	.501**	485**	.138	.336	.081	-.368*	-.323
LIFEL	.571**	1.000	.792**	.717**	.816**	.582**	-.066	.240	.015	-.059	-.040
PUBRD	.405*	.792**	1.000	.740**	.750**	.451**	-.141	.330	.240	.033	-.208
BUSRD	.417*	.717**	.740**	1.000	.806**	.791**	-.118	.666**	.502**	.234	.171
PUBL	.501**	.816**	.750**	.806**	1.000	.722**	-.055	.557**	.252	.142	.055
PAT	.485**	.582**	.451**	.791**	.722**	1.000	-.123	.646**	.215	.107	.215
NON	.138	-.066	-.141	-.118	-.055	-.123	1.000	.249	.148	-.052	-.077
PROD	.336	.240	.330	.666**	.557**	.646**	.249	1.000	.804**	.083	-.054
MARK	.081	.015	.240	.502**	.252	.215	.148	.804**	1.000	-.198	-.148
TECH_ EMPL	-.368*	-.059	.033	.234	.142	.107	-.052	.083	-.198	1.000	.681**
TECH_ EXP	-.323	-.040	-.208	.171	.055	.215	-.077	-.054	-.148	.681**	1.000

Source: authors calculations based on the Eurostat and Inno-metrics data. N=32; * - significance level 0.05; ** significance level 0.01

Appendix 2. Factor scores and composite indicators for assessing national innovation performance, EU-27 and selected European countries, 2008

Country	F1	F2	F3	Composite indicator.based on weighted scores	EIS-2008	EIS-2008. re-scaled
BE	0.150	0.951	0.087	0.279	0.507	0.027
BG	-0.776	- 1.466	-0.678	-0.762	0.221	-0.259
CZ	-0.432	-0.331	1.788	0.111	0.404	-0.076
DK	1.617	-0.235	-0.069	0.600	0.570	0.090
DE	0.088	2.478	1.418	0.840	0.581	0.101
EE	**-0.412**	**0.795**	**-0.995**	**-0.201**	**0.454**	**-0.026**
IE	-0.149	0.406	-0.291	-0.034	0.533	0.053
EL	-1.123	0.973	-1.191	-0.494	0.361	-0.119
ES	0.036	-0.749	-0.175	-0.177	0.366	-0.114
FR	0.241	0.136	0.623	0.252	0.497	0.017
IT	-0.476	0.066	0.749	-0.031	0.354	-0.126
CY	-0.223	0.514	-1.590	-0.302	0.471	-0.009
LV	**-0.670**	**-0.727**	**-1.132**	**-0.654**	**0.239**	**-0.241**
LT	**-0.327**	**-1.386**	**-1.192**	**-0.664**	**0.294**	**-0.186**
LU	-0.802	1.816	-1.305	-0.208	0.524	0.044
HU	-0.462	-1.256	1.479	-0.157	0.316	-0.164
MT	-0.960	-0.726	1.293	-0.288	0.329	-0.151
NL	0.983	-0.539	-0.403	0.209	0.484	0.004
AT	0.326	1.598	0.687	0.607	0.534	0.054
PL	-0.749	-1.044	0.304	-0.466	0.305	-0.175
PT	-1.042	1.111	-0.308	-0.255	0.364	-0.116
RO	-1.103	-0.541	0.322	-0.502	0.277	-0.203
SI	0.050	-0.232	0.868	0.145	0.446	-0.034
SK	-0.869	-1.049	1.681	-0.240	0.314	-0.166
FI	1.786	0.836	0.347	0.977	0.610	0.130
SE	2.139	-0.303	0.320	0.877	0.637	0.157
UK	1.184	-1.221	0.236	0.276	0.547	0.067
HR	-0.704	-0.170	-0.221	-0.369	0.293	-0.187
TR	-1.606	0.589	-0.425	-0.620	0.205	-0.275
IS	1.676	-0.791	-1.653	0.191	0.467	-0.013
NO	0.920	-0.517	-1.541	-0.040	0.380	-0.100
CH	1.689	1.015	0.968	1.099	0.681	0.201

Source: authors' calculations based on Eurostat and Inno-metrics data

Appendix 3. Factor scores and composite indicators for assessing national innovation performance with inclusion of the initial variable NON_R&D_INNO forEU-27 and selected European countries, 2008

Country	F1	F2	F3	Composite indicator (based on weighted scores)	EIS-2008	EIS-2008. re-scaled
BE	0.319	0.726	0.176	0.290	0.507	0.027
BG	-1.025	-1.228	-0.798	-0.781	0.221	-0.259
CZ	-0.283	-0.294	1.891	0.215	0.404	-0.076
DK	1.601	-0.505	-0.114	0.511	0.570	0.090
DE	0.444	2.129	1.614	0.879	0.581	0.101
EE	**-0.673**	**2.592**	**-1.050**	**-0.006**	**0.454**	**-0.026**
IE	-0.106	0.328	-0.273	-0.037	0.533	0.053
EL	-0.837	0.858	-0.967	-0.365	0.361	-0.119
ES	-0.092	-0.731	-0.262	-0.220	0.366	-0.114
FR	0.289	-0.129	0.627	0.215	0.497	0.017
IT	-0.516	0.020	0.724	-0.053	0.354	-0.126
CY	-0.301	0.656	-1.631	-0.325	0.471	-0.009
LV	**-0.814**	**-0.631**	**-1.197**	**-0.670**	**0.239**	**-0.241**
LT	**-0.473**	**-1.320**	**-1.262**	**-0.674**	**0.294**	**-0.186**
LU	-0.602	1.588	-1.177	-0.184	0.524	0.044
HU	-0.551	-1.174	1.418	-0.143	0.316	-0.164
MT	-1.260	-0.750	1.071	-0.412	0.329	-0.151
NL	0.875	-0.765	-0.508	0.102	0.484	0.004
AT	0.561	1.295	0.810	0.614	0.534	0.054
PL	-0.875	-0.937	0.238	-0.462	0.305	-0.175
PT	-0.748	1.078	-0.087	-0.115	0.364	-0.116
RO	-1.100	-0.407	0.356	-0.431	0.277	-0.203
SI	0.126	-0.047	0.929	0.226	0.446	-0.034
SK	-1.075	-0.855	1.552	-0.263	0.314	-0.166
FI	1.847	0.607	0.334	0.896	0.610	0.130
SE	2.205	-0.449	0.318	0.843	0.637	0.157
UK	0.907	-1.236	0.015	0.135	0.547	0.067
HR	-0.624	-0.071	-0.135	-0.283	0.293	-0.187
TR	-1.334	0.476	-0.209	-0.476	0.205	-0.275
IS	1.669	-0.656	-1.634	0.206	0.467	-0.013
NO	0.763	-0.783	-1.649	-0.173	0.380	-0.100
CH	0.319	0.726	0.176	0.290	0.681	0.201

Source: authors' calculations based on Eurostat and Inno-metrics data