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THE LUXEMBOURG COMPETITIVENESS INDEX: ANALYSIS & RECOMMENDATIONS

Michaela Saisana

MINISTÈRE DE L'ÉCONOMIE
ET DU COMMERCE EXTÉRIEUR
Observatoire de la compétitivité

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Michaela Saisana

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Executive summary

The 2008 Competitiveness Index, developed by the Observatoire de la Compétitivité distils key aspects of competitiveness in ten main categories along the lines of the Fontagné report: (1) Macroeconomic performance, (2) Employment, (3) Productivity & Labour Cost, (4) Market Operations, (5) Institutional and Regulatory Framework, (6) Entrepreneurship, (7) Education & Training, (8) Knowledge economy, (9) Social Cohesion, and finally (10) Environment. These categories include a total of 82 indicators.

The difference between the Scoreboard of Competitiveness of the Fontagné report and similar indices on competitiveness is that it has been tailor-made to the needs of the European Union, including also almost all the Lisbon indicators. Furthermore, the Observatoire de la Compétitivité is very clear about the definition of competitiveness:

"Competitiveness is the capacity of a nation to durably improve the standard of living of its inhabitants and to procure for them high levels of employment and social cohesion while preserving the environment."

In this respect, the concept underlying competitiveness as measured by the Observatoire de la Compétitivité and that of the World Economic Forum for example, are quite distinct.

The present study aims to critically assess the methodological approach taken by the Observatoire de la Compétitivité to build the EU Competitiveness Index (2008 data), by addressing two key questions:

- Can the Scoreboard of Competitiveness of the Fontagné report be used as a conceptual framework for building an Index - what are the necessary changes?

- What scenarios could have been used to build the Index and how do the results of these scenarios compare to the original results?

The analysis and the subsequent recommendations of the present report follow the guidelines offered in the OECD (2008) Handbook on Composite Indicators and elicit from the lessons learnt from similar assessments carried out on other known composite indicators, such as the Environmental Performance Index, the Multi-dimensional Poverty Assessment Tool and the Index of African Governance.

Regarding the first objective, correlation analysis between the underlying indicators, categories and the final Index, is used to study the coherence of the conceptual framework and identify what actions are needed in order to translate the Scoreboard into a suitable conceptual framework for constructing an Index.

In line with the second objective, an ex post analysis is performed to evaluate the robustness of the 2008 Index ranking against alternative scenarios in which different sources of uncertainty are activated simultaneously. In these more sophisticated scenarios we deviate from the reference approach used by the Observatoire de la Compétitivité – simple average across and within the ten categories, where indicators were normalised using a Min-Max scaling and missing data were not imputed. The alternative scenarios we consider differ from one another in the degree of measurement error in the raw data, the treatment of outliers, the imputation of missing data, the normalisation method, the aggregation rule at the categories level and the inclusion/exclusion of a category. Such a multi-modelling approach and the presentation of the results under uncertainty, rather than as single country ranks, helps to avert the criticism that composite measures and rankings are presented as if they had been calculated under conditions of certainty, while this is in fact rarely the case.

The overall assessment of the 2008 Index by means of correlation analysis and uncertainty and sensitivity analyses reveals that although the Competitiveness Scoreboard from the Fontagné report is a good basis for building an Index, it needs to be revised to overcome few shortcomings (summarised in the Conclusions of this report). In brief, the analyses demonstrate that the 2008 Competitiveness Index

- needs to correct for few outlier values that can strongly distort the correlation structure and strongly impact the results,
- is in most cases not double-counting information (but there are few pairs of highly correlated indicators that need to be combined),
- is multidimensional but there are some indicators that exhibit a strongly autonomous behaviour, not statically significant correlated to any of the other indicators, categories, or the final index and could hence be excluded from the framework,
- is not dominated by a single category, but needs a better actual balance in its ten categories, e.g. by adjusting the weights attached to the indicators and to the categories, so as to effectively apply an equal weighting scheme,
- may need a normalisation of the categories (in addition to the normalisation of the indicators);
- is not strongly affected by compensability (at the category level),
- is not biased with respect to population size or land area (neither are the ten categories), and
- is a good average summary measure of a plurality of alternative scenarios.

Data-driven narratives on competitiveness issues in the European Union are also offered in order to draw attention to messages and debates that may stem from an index-based analysis of competitiveness. Important findings suggest that:

(a) The Entrepreneurship and Knowledge Economy categories pose the highest challenges for competitiveness at the EU scale – half of the EU countries do not score more than 40 points (best possible score is 100 points).

(b) The distances between the most and least competitive EU countries are small – the top 5 countries score between 59 and 63 points (Denmark, Finland, the Netherlands, Sweden, and UK, alphabetical order), whilst the bottom 5 countries score between 43 and 47 points (Hungary, Latvia, Malta, Poland, and Portugal, alphabetical order).

(c) There is space for improvement in all EU countries – e.g., the UK is ranked in the top 7 overall but bottom 7 in Macroeconomic Performance and Knowledge Economy. Similarly, Denmark, Finland and Sweden are top 7 overall but bottom 7 in Entrepreneurship. On the other hand, some countries excel in a single category, but remain in the bottom 7 in the overall classification (Latvia excels in Market Operations, Malta in the Institutional & Regulatory Framework and in the Social Cohesion, Poland and Portugal in Entrepreneurship, Lithuania in Education &Training, and Hungary excels in the Environment category).

The auditing conducted herein has shown the potential of the Competitiveness Index developed by the Observatoire de la Compétitivité, upon some refinements, in reliably identifying weaknesses and ultimately monitoring national performance in the EU countries.

Michaela Saisana

1. Introduction

The Competitiveness Index developed by the *Observatoire de la Compétitivité*, a collaboration between Luxembourg's Ministry of Economy and Foreign Trade and STATEC[1], aims to measure the multidimensional aspects of EU competitiveness at national level and over time (first edition: 2000 data, latest edition:2008 data). The Index follows a ten-category conceptual structure composed of: (1) *Macroeconomic performance*, (2) *Employment*, (3) *Productivity & Labour Cost*, (4) *Market Operations*, (5) *Institutional and Regulatory Framework*, (6) *Entrepreneurship*, (7) *Education & Training*, (8*) Knowledge economy*, (9) *Social Cohesion*, and finally (10) *Environment*.

The ten categories of competitiveness are described by 82 indicators, all in quantitative measurement scales. The categories and the indicators were chosen on the basis of the Fontagné report entitled "La compétitivité: Une paille dans l'acier" (2004)[2]. It is important to add that the Fontagné report was meant to serve as a Scoreboard on Competitiveness, not necessarily as a conceptual framework for constructing a Competitiveness Index.

The *Observatoire de la Compétitivité* took the Scoreboard a step further, and used it as a conceptual framework with a view to summarise in a single measure the competitiveness performance of the 27 EU countries. The main approach to the realisation of the final Index was straightforward: the raw data (without imputation for missing data) were transformed using the min-max normalisation method in a [0, 100] scale and a simple average was employed at both levels of aggregation (categories, overall Index).

Competitiveness is clearly an abstract concept that cannot be measured directly. The underlying hypothesis of this kind of analysis is that the phenomenon represents a latent factor that may be observed only indirectly by several indicators describing different features/aspects of the latent dimension. Choosing different aspects and indicators is equivalent to choosing the 'conceptual framework' of the index. This framework may be seen as the 'measurement instrument' of the latent phenomenon.

According to the conceptual framework, which should be developed on the basis of general reasoning, expert opinion and/or practitioners' advice, data are usually collected

[1] Bilan Compétitivité 2008 - «Préparer l'après-crise» available at: http://www.odc.public.lu/
[2] Lionel Fontagné (2004), *Compétitivité du Luxembourg : Une paille dans l'acier*. http://www.odc.public.lu/publications/perspectives/PPE_3.pdf

for the set of units under investigation (i.e. countries in the present case). Once data have been collected, various statistical methods can be used to:

- assess the validity of the conceptual framework;
- set up the final measure of the phenomenon;
- assess the robustness of the index with respect to different choices regarding either the framework or the computational method of the index (statistical methods, aggregation schemes, etc.).

The present study aims to critically assess the methodological approach taken by the *Observatoire de la Compétitivité* to build the EU Competitiveness Index, by addressing two key questions:

- *Can the Scoreboard of Competitiveness of the Fontagné report be used as a conceptual framework for building an Index - what are the necessary changes?*

- *What scenarios could have been used to build the Index and how do the results of these scenarios compare to the original results?*

Both questions are addressed by analysing the n 2008 data.

The analysis and the subsequent recommendations of the present report follow the guidelines offered in the OECD (2008) Handbook on Composite Indicators and elicit from the lessons learnt from similar assessments carried out on other known composite indicators, such as the Environmental Performance Index[3], the Multi-dimensional Poverty Assessment Tool[4], the Index of African Governance[5], and the Composite Learning Index[6].

The structure of the report is as follows. **Section 2** describes the Scoreboard of Competitiveness of the Fontagné report (categories and indicators), and the methodological approach used by the *Observatoire de la Compétitivité* to build the Competitiveness Index. **Section 3** discusses missing data, oultier detection and other data issues and provides suggestions on improving data quality aspects. **Section 4** deals

[3] Saisana M., and Saltelli A., 2010, Uncertainty and Sensitivity Analysis of the 2010 Environmental Performance Index, EUR 56990 EN, European Commission- JRC-IPSC, Italy.
[4] Saisana M., and Saltelli A., 2010, The Multidimensional Poverty Assessment Tool (MPAT): Robustness issues and Critical assessment, EUR 24310 EN, European Commission- JRC-IPSC, Italy.
[5] Saisana M., Annoni, P, Nardo M., 2009, A robust model to measure African Governance: Robustness Issues and Critical Assessment, EUR 23274 EN, European Commission, JRC-IPSC, Italy.
[6] Saisana M., 2008, The 2007 Composite Learning Index: Robustness Issues and Critical Assessment, EUR 23274 EN, European Commission, JRC-IPSC, Italy.

with eventual refinements needed to transform the Scoreboard of Competitiveness into a conceptual framework for building a Competitiveness Index for the European Union based on an analysis of the correlation structures within and across categories. In **Section 5**, we carry out an uncertainty and sensitivity analysis of the Index. We aim to examine to what extent the 2008 country ranking depends on the choices made by the *Observatoire de la Compétitivité*. The analysis involves the simultaneous activation of various sources of uncertainty (e.g. imputation of missing values, treatment of outliers, normalisation of raw data, aggregation rule at the category level). **Section 6** discusses data-driven narratives based on the 2008 Index results and suggests which aspects of competitiveness represent the main challenges in the EU countries. **Section 7** summarizes the aims, the main findings and the recommendations of the study.

2. Conceptual framework and methodology

Attempting to summarize a complex system such as competitiveness in a single metric can pose a number of practical challenges, e.g. data quality, indicator selection, indicator importance. However, if done properly, the exercise could yield a powerful comparative assessment tool capable of capturing the societal conditions that determine competitiveness. It could allow for country comparisons across space and time by providing the technical ability to monitor change, identify problems and contribute to priority-setting and policy formulation. Thus, an index of competitiveness in the EU countries could reveal new knowledge which otherwise would remain invisible.

There are several indices capturing competitiveness or attractiveness of doing business in a single number, from the most known ranking of the World Economic Forum, the International Institute for Management Development and the Heritage Foundation, to the less known to the general public, "Doing business" of the World Bank, the European Competitiveness Index by Huggins, the Nation Brands Index by Anholt-GfK Roper and various other fiscal attractiveness studies such as those by BAK Basel and Ernst & Young (for a review see *Observatoire de la Compétitivité*, 2008).

The difference between the Scoreboard of Competitiveness of the Fontagné report and other similar indices is that it has been tailor-made to the needs of the European Union, including almost all Lisbon indicators. Furthermore, the Observatoire de la Compétitivité is very clear about the definition of competitiveness:

"*Competitiveness is the capacity of a nation to durably improve the standard of living of its inhabitants and to procure for them high levels of employment and social cohesion while preserving the environment.*"

In this respect, the concept of competitiveness underlying the Index by the Observatoire de la Compétitivité and that of the World Economic Forum, for example, are quite distinct.

The conceptual framework of the Competitiveness Index that was selected by the Observatoire de la Compétitivité originates in the Scoreboard of the Fontagné report and analyses competitiveness through the economic, social and environmental pillars of sustainable development. There are 82 indicators (in the 2008 dataset) that are grouped in ten categories (there are four to fifteen indicators per category) and finally aggregated to a final Index. The ten categories represent various aspects of competitiveness, i.e.

1. *Macroeconomic performance*,
2. *Employment*,
3. *Productivity & Labour Cost*,
4. *Market Operations*,
5. *Institutional and Regulatory Framework*,
6. *Entrepreneurship*,
7. *Education & Training*,
8. *Knowledge economy*,
9. *Social Cohesion*, and finally
10. *Environment*.

All 82 indicators are expressed in quantitative measurement scales. The Observatoire de la Compétitivité opted not to impute missing data, but instead to calculate country scores per category and for the final Index by averaging the available indicator values.

Table 1 presents the ten categories and the underlying indicators. These indicators reflect a wide range of competitiveness issues ranging from unemployment /employment rates and public debt, to factor productivity and labour costs, to electricity and gas prices, corporate taxes and standard vat rates, propensity for entrepreneurialism, university attainment and lifelong learning, income inequality and at risk poverty rates, greenhouse gas emissions and energy intensity of the economy.

The construction of the final Index is straightforward: a simple average at both levels of aggregation (from the underlying indicators to the categories, from the categories to the overall Index). Raw data values are first normalized by a min-max approach - all indicators are rescaled such that the worst value in a given year receives a score of "0", and the best value in a given year gets a score of "100".

Formula if higher indicator values are desirable:

$$I_{qc}^{t} = \frac{x_{qc}^{t} - \min_{c}(x_{q}^{t_0})}{\max_{c}(x_{q}^{t_0}) - \min_{c}(x_{q}^{t_0})} \tag{1}$$

Formula if lower indicator values are desirable:

$$I_{qc}^{t} = \frac{\max_c(x_q^{t_0}) - x_{qc}^{t}}{\max_c(x_q^{t_0}) - \min_c(x_q^{t_0})} \tag{2}$$

Where x_{qc}^{t} is the value of indicator q for country c at time t.

The composite indicator is then calculated by:

$$CI_c = \sum_{q=1}^{Q} w_q I_{qc} \tag{3}$$

with $\sum_q w_q = 1$ and $0 \le w_q \le 1$, for all $q=1,..,Q$ and $c=1,\ldots,M$.

The Observatoire de la Compétitivité opted not to impute missing data, but instead to calculate country scores per category and for the final Index by averaging the available indicator values.

Table 1. Competitiveness Scoreboard – 2008 data

Category A: Macroeconomic performance (12 indicators) A1. Gross National Income per capita (PPS) A2. Real growth rate of GDP (*) A3. Growth in domestic employment A4. Unemployment rate (%) (-) A5. Inflation rate (%)(-) A6. Public balance as a % of GDP A7. Public debt as a % of GDP (-) A8. Gross fixed capital formation- public admin. A9. Terms of trade (-) A10. Real effective exchange rate (1995=100) (-) A11. Diversification – entropy coefficient **A12.** FDI inflows/outflows	**Category B: Employment (9 indicators)** B1. Employment rate (*) B2. Employment rate (male) (*) B3. Employment rate (female) (*) B4. Employment rate of persons 55y -64y (total) (*) B5. Employment rate of persons 55y-64y (male) (*) B6. Employment rate of persons 55y-64y (female) (*) B7. Unemployment rate of persons under 25y (-) B8. Long-term unemployment rate (*)(-) B9. Persons holding a part-time job
Category C: Productivity & Labour Cost (5 indicators) C1. Trends in total factor productivity C2. Trends in apparent work productivity C3. Productivity per hour worked (% of U.S.) C4. Changes in unit labour costs (-) C5. Costs / Revenue ratio in the banking sector (-)	**Category D: Market Operations (9 indicators)** D1. ~~Percentage of full-time workers on minimum wage~~ D2. Price of electricity (ex-VAT) – industrial users (-) D3. Price of gas (ex-VAT) - industrial users (-) D4. Market share of the primary operator in the cellular telephone market (-) D5. Composite basket of fixed and cellular telecommunications (ex-VAT) (-) D6. Composite basket of cellular telephone royalties (ex-VAT) (-) D7. Broad band Internet access rates (-) D8. Basket of domestic royalties for 2Mbits leased lines (ex-VAT) (-) D9. Public markets – value of public markets using open procedure procurement

	D10. Total of State aid as a % of GDP (excluding horizontal objectives) (-) D11~~. Market share of primary operator in the fixed telephone market~~
Category E: Institutional and Regulatory Framework **(10 indicators)** E1. Corporate taxes (-) E2. Public sector payroll costs (-) E3. Standard VAT rate (-) E4. Tax wedge: Single, without children (-) E5. Tax wedge: Married, with 2 children, one wage-earner (-) E6. Administration efficiency index E7. Observance of the law index E8. Regulatory quality index E9. Degree of sophistication of online public services E10. Public services fully available online.	**Category F: Entrepreneurship** **(4 indicators)** F1. Propensity for entrepreneurialism F2. Self-employed jobs as a percentage of total employment F3. Net change in number of companies (start-up rate less close-down rate) F4. Volatility among companies (start-up rate plus closedown rate
Category G: Education & Training **(5 indicators)** G1. Annual cost per student in public educational facilities (-) G2. Portion of the population aged 25-64 with a secondary education G3. ~~Portion of the population aged 25-64 with a university education~~ G4. Percentage of human resources in scientific and technological fields as a % of total employment G5. Lifelong learning (participation of adults in training and teaching programs) G6.Secondary school dropouts (-)	**Category H: Knowledge economy** **(15 indicators)** H1. Internal R&D expenditure (*) H2. Public R&D budget credits H3. Portion of public research financed by the private sector H4. Percentage of sales allocated to the introduction of new products on the market (new or significantly improved products) H5. Number of researchers per 1,000 employed persons H6. Scientific publications per million inhabitants H7. Number of patents USPTO per million inhab. H8. Number of patents OEB per million inhabitants H9. Use of Internet by companies (broad band) H10. Investment in public telecommunications as a percentage of gross fixed capital formation H11. Percentage of households that have Internet access at home H12. Number of cell phones per 100 inhabitants H13. Percentage of households that have broad band Internet access H14. Number of secure web servers per 100,000 inhabitants H15. Percentage of total employment in medium or high technology sectors
Category I: Social Cohesion (6 indicators) I1. Gini Coefficient (-) I2. At-risk of poverty rate after social transfers (*)(-) I3. At persistent risk of poverty rate (-) I4. Life expectancy at birth I5. Wage gap between men and women (-) I6. Serious work accidents (-)	**Category J: Environment (7 indicators)** J1. Number of ISO 14001per thousand companies J2. Number of ISO 9001 per thousand companies J3. Total greenhouse gas emissions (*)(-) J4. Percentage of renewable energy sources J5. Volume of municipal waste generated (-) J6. Energy intensity of the economy (*)(-) J7. Modal split in transportation choice-percentage of car users as transportation method (-)

Source: Fontagné (2004). Notes: (*) Lisbon indicator; (-) the lower the indicator value, the better for competitiveness

3. Data quality issues

3.1. Reproducing the Index results

Transparency to stakeholders is considered to be an essential ingredient of well-built composite indicators (OECD, 2008). A clear understanding of the Competitiveness Index methodology is also necessary with a view to perform the robustness assessment of the index. Thus, the first test has been: is it possible to reproduce the Index ranking given the data and information provided to the public? The answer is "*Yes*". The relevant documentation on the 2008 *Bilan Compétitivité* by the *Observatoire de la Compétitivité* provides enough information to a statistically literate public in order to replicate the methodology and the results. The Competitiveness Index is clear about its definition, its framework, its underlying indicators, its methodological assumptions, and does not fall under the critiques of normative ambiguity at times addressed to composite indicators (see Stiglitz report, p. 65).

During this re-production phase, we encountered a possible switch in four country names in the final results in the 2008 *Bilan Compétitivité*: the scores for Romania have erroneously been assigned to Slovakia, and vice versa, and the scores for the United Kingdom have erroneously been assigned to Czech Republic, and vice versa.

3.2. Asymmetric distributions and outlier detection

We next assessed the appropriateness of using the min-max method to normalise the raw data. The min-max method (see Equations 1 and 2) is in general sensitive to outliers, which, if not treated properly, could become unintended benchmarks. Furthermore, outliers can have a strong impact on the correlation structure (see analysis in Chapter 4), and hence introduce bias in the interpretation of the results. There are many methods suitable for outlier detection, but in the context of composite indicator building the combined use of skewness and kurtosis could be particularly apt. A skewness value greater than 1 together with a kurtosis value greater than 3.5 (both in absolute terms) could flag problematic indicators that need to be treated before the final index construction (Groeneveld and Meeden, 1984).

In the 2008 dataset, seven indicators are flagged for further consideration as they exhibit relative high values for skewness and kurtosis (Table 2): gross national income (A1), terms of trade (A9), FDI inflows/outflows (A12), market share of primary operator in

the cellular market (D4), basket of domestic royalties for 2Mbits leased lines (D8), number of researchers (H5), and energy intensity of the economy (J6).

Potential outliers could be identified either visually (as shown in Figure 1) or using information based on the inter-quartiles range, namely outside the range:

$$\begin{aligned} &\text{Lower boundary: } L = Q_1 - 1.5 \cdot (Q_3 - Q_1) \\ &\text{Upper boundary: } U = Q_3 + 1.5 \cdot (Q_3 - Q_1) \end{aligned} \tag{4}$$

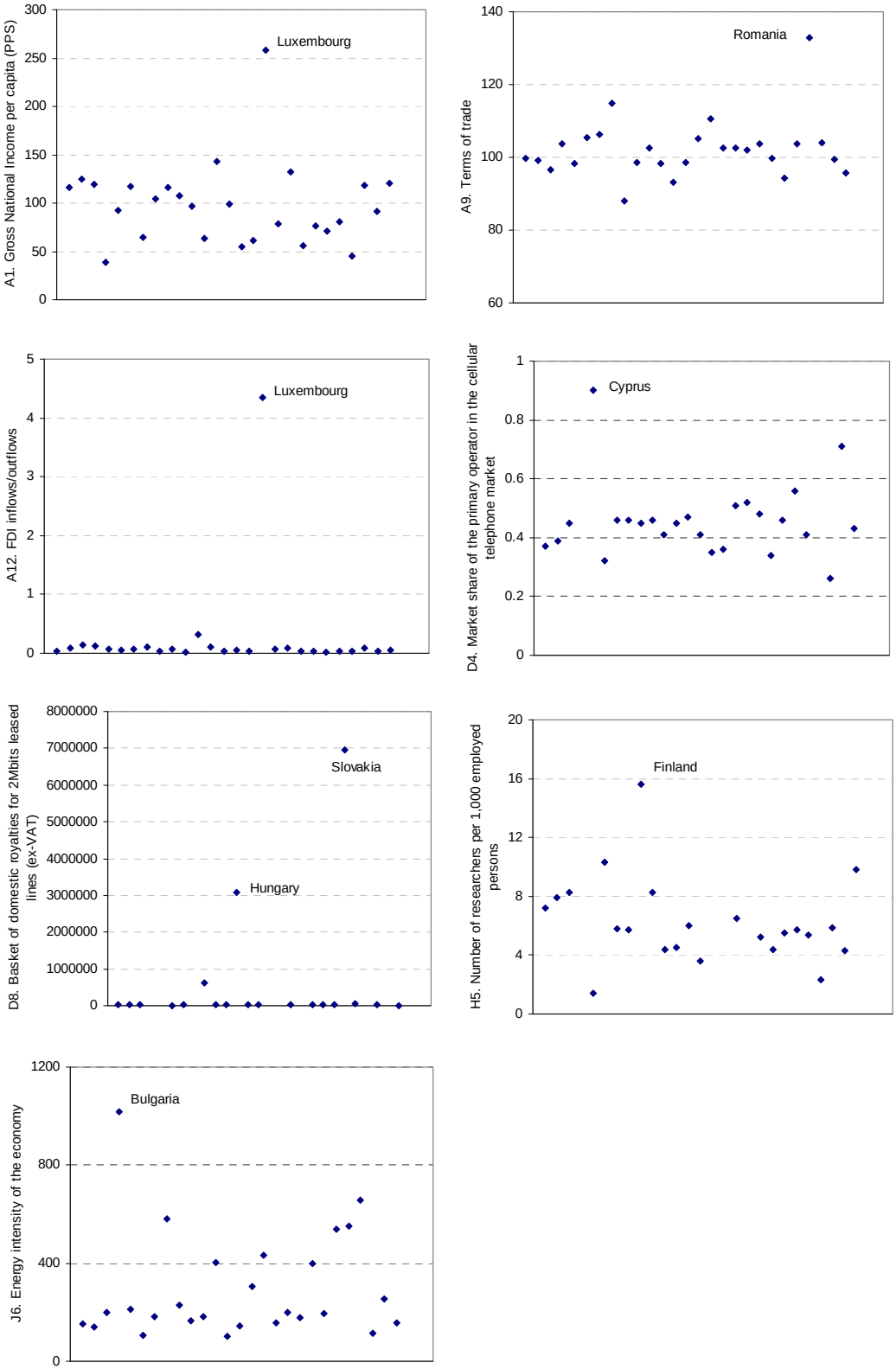
where Q_1 and Q_3 are respectively the first and the third quartile (Tukey, 1977). We will briefly refer to this method as the inter-quartiles range.

Both the visual approach and the inter-quartiles range spot the same outlier values: two values for the indicator basket of domestic royalties for 2Mbits leased lines (D8) and a single value for the remaining six indicators. Just to give an example, for gross national income (A1), the value 258 for Luxembourg is clearly an outlier (the second best value is merely 143 for Ireland). Given that only one (worst case two) value was identified as outlier in some of the indicators, we have preferred not to apply any transformation (e.g., taking logarithms, Box-Cox, or other), but simply to winsorize the outlier values by resetting them to the second (or third best) value as shown in Table 2. For the example discussed, this winsorization implies that upon rescaling with a min-max method, both Luxembourg and Ireland will get a normalised score of 100.0 for gross national income. Descriptive statistics for all 82 indicators in the dataset are presented in the Annex.

Table 2. Outlier detection and treatment

Indicator	***N***	***Skewness***	***Kurtosis***	***Outlier treatment***
A1. Gross National Income per capita	27	1.92	6.69	Value 258 for Luxembourg set to 143 (= Ireland)
A9. Terms of trade	27	2.05	7.29	Value 132 for Romania set to 115 (= Estonia)
A12. FDI inflows/ outflows	27	5.13	26.50	Value 4.355 for Luxembourg set to 0.325 (= Hungary)
D4. Market share-primary operator, cellular phone	25	1.99	5.83	Value 0.9 Cyprus set to 0.71 (= Slovenia)
D8. Basket of domestic royalties for 2Mbits leased lines	19	3.46	12.30	Value 6,957,370 for Slovakia and 3,067,549 for Hungary set to 613,836 (= Finland)
H5. Number of researchers	23	1.40	3.61	Value 15.6 for Finland set to 10.3 (= Denmark)
J6. Energy intensity of the economy	27	1.82	3.61	Value 1016.29 for Bulgaria set to 655.59 (= Romania)

Figure 1.Problematic indicators (outliers)



3.3 Data coverage and missing values

Data quality tests focused next on availability at all levels: indicators, categories, countries. The 2008 dataset is characterized by excellent data coverage (92.3%, matrix of 82 ×27) as shown in Table 3. Four of the ten categories − Macroeconomic Performance, Employment, Education & Training, and Environment − have 97% or more data availability. Only two categories− Market Operations, Entrepreneurship− miss roughly 15% of the data values, which is still acceptable according to some rules of thumb for data availability of at least 75%.

Data availability checks at country level show that in general data coverage is satisfactory, but there are few countries with important data gaps (Table 4). On the positive side, eight of the EU27 countries – Belgium, Denmark, Finland, France, Italy, Luxembourg, Netherlands, Portugal − do not miss any of the 82 values needed to build the Index. Most of the remaining countries miss merely one or two values and no country misses more than 25% of the values (worst case: Malta lacks 19 values out of 82). Caution is needed, however, when estimating and interpreting the category scores for those countries that miss almost half or more values within the category. This is the case for Malta, Bulgaria, Cyprus, Romania, Lithuania, Lithuania, Estonia, Slovenia, Greece, Poland, Ireland and Germany for one or more categories on Market Operations, Entrepreneurship and Knowledge Economy. It is recommended that a note on poor data coverage is added regarding the countries and categories discussed above.

At the indicator level, 59 indicators do not miss a single value (Table 5). However, twelve indicators miss values for almost one-forth of the countries and two indicators − trends in total factor productivity (C1) and at persistent risk of poverty rate (I3) miss more than half of the country values. According to general guidelines for composite indicator development, one should eliminate these two indicators from the calculation of the Index. In the present case, given that the Index is made of 82 indicators, eliminating the indicators C1 and I3 would leave the results practically unaffected. In any case it is recommended that the two indicators are maintained in the conceptual framework but a note on poor data coverage is added.

Table 3. Missing data issues- category level

Category of the Competitiveness Scoreboard	***Missing data***	***Number of indicators***	***Missing data***
A: Macroeconomic performance	8	12	2.5%
B: Employment	0	9	0.0%
C: Productivity & Labour Cost	12	5	8.9%
D: Market Operations	37	9	15.2%
E: Institutional & Regulatory Framework	18	10	6.7%
F: Entrepreneurship	15	4	13.9%
G: Education & Training	0	5	0.0%
H: Knowledge Economy	44	15	10.9%
I: Social Cohesion	13	6	8.0%
J: Environment	2	7	1.1%
Total			6.7%

Table 4. Missing data issues –country level

Countries with missing data	***Missing values (total of 82)***
Malta [D,F,H]	19
Bulgaria [D,H]	18
Cyprus [D,F]	17
Romania [D,H]	16
Lithuania [D,H]	15
Latvia [D,H]	14
Estonia [D,H] Slovenia [D,H]	13
Greece[F], Poland[F]	4
Irland[F]	3
Germany[F], Hungary, Slovakia, Sweden, Czech Republic	2
Austria, Spain, United Kingdom	1
Belgium, Denmark, Finland, France, Italy, Luxembourg, Netherlands, Portugal	0

Notes:
[D] caution when interpreting the country rank in Category D (almost half or more missing data)
[F] caution when interpreting the country rank in Category F (half or more missing data)
[H] caution when interpreting the country rank in Category H (half or more missing data)

Table 5. Missing data issues – indicator level

Indicators with missing data	***Missing values (total of 27)***
I3	13
C1	12
A10, D5, D6, D7, D8, E4, E5, H3, H4, H10, H12, H14	8
F3, F4	6
H5	4
D3	3
D4, E2, F1, J7	2
F2	1
59 indicators have no missing data	0

Notes: Full indicator names are given in Table 1.

3.4. Estimating missing values

A further data quality issue relates to the treatment of missing values. The *Observatoire de la Compétitivité* opted not to impute missing data, but instead to calculate country scores per category and for the Index by averaging the available indicator values. An alternative approach known as *mean substitution* was also considered by the team. Mean substitution entails filling the missing country cells with the mean value of the same indicator calculated over all the available country values.

Both approaches, namely no missing data treatment or mean substitution could be good starting points; however they both have notable shortcomings. The former approach is also known as *no imputation*, but in essence it implies replacing missing values per country with the weighted average of all available indicators' values for the given country. On the other hand, *mean substitution* will artificially diminish the variance of an indicator by imputing the same value for each missing datum. A reduced variance can either attenuate correlation or, if the same country data are missing for two indicators, can inflate it. Furthermore, with *mean substitution* no additional information offered by other indicators is used.

We would recommend using the *hot-deck* method (single imputation), in which recorded units in the sample are used to substitute missing values (Little and Rubin, 2002). It involves substituting individual values drawn from "similar" observed units, similarity being defined as a certain distance. The distance between two countries i and j was calculated using the Manhattan distance:

$$d_{ij} = \sum_k \left| {}_k x_i - {}_k x_j \right| \quad (5)$$

where ${}_k x_i$ is the value of indicator *k* observed for country *i* and *k* varies only across those indicators which are observed for both countries. The Manhattan distance (absolute of differences between points) was preferred here as the Euclidean distance was found to over-weight high differences in some cases (Little & Rubin, 2002).

Table 6. Missing data imputed with hot deck method (Manhattan distance)

	Propensity for entrepreneurialism (F1)	***Self-employed jobs (F2)***	***Net change in number of companies (F3)***	***Volatility among companies (F4)***
Germany	0.41	0.11071	0.0262	0.1622
Austria	0.355	0.0886	0.0219	0.1439
Belgium	0.304	0.16005	-0.0164	0.1572
Bulgaria	0.551	0.26277	0.0065	0.2313
Cyprus	0.542	0.17468	-0.0149	0.2811
Denmark	0.357	0.0625	-0.0716	0.135
Spain	0.402	0.13842	0.0349	0.1737
Estonia	0.4	0.079316	0.0064	0.2132
Finland	0.347	0.0886	0.0134	0.1492
France	0.411	0.12016	0.0262	0.1622
Greece	0.558	0.3475	0.0025	0.1529
Hungary	0.428	0.12296	-0.0301	0.2101
Ireland	0.558	0.1751	-0.0149	0.2811
Italy	0.551	0.23715	0.0025	0.1529
Latvia	0.499	0.10179	0.0359	0.1931
Lithuania	0.578	0.11498	0.0145	0.1915
Luxembourg	0.35	0.057307	0.0284	0.194
Malta	0.447	0.11656	-0.0301	0.2101
Netherlands	0.346	0.13771	0.0014	0.1732
Poland	0.51	0.2356	0.0025	0.1529
Portugal	0.567	0.18535	-0.0149	0.2811
Slovakia	0.359	0.15199	0.0537	0.1573
Czech Republic	0.296	0.1815	-0.0254	0.1996
Romania	0.567	0.3241	0.0935	0.2723
United Kingdom	0.493	0.1303	0.0297	0.2439
Slovenia	0.317	0.1697	0.0346	0.1418
Sweden	0.349	0.052862	0.0141	0.1263

Pairs of "most similar" countries are shown in Table 6 for the Entrepreneurship category (F), where squared cells indicate the estimates for missing values based on the hot-deck method. For example, the performance of Austria in three underlying indicators of this category resembles the most the performance of Finland. Therefore, for Austria the estimated value for self-employed jobs (F2) is 0.0886 (equal to that of Finland). Portugal is the most similar country to Ireland, Cyprus and Romania, and therefore the missing values for those three countries are estimated based on those of Portugal.

Various versions of the hot-deck imputation method exist, using for example different distance measures. Any of these approaches are preferred over the simple mean substitution or "no imputation" options, which were originally considered for the missing data treatment by the *Observatoire de la Compétitivité*. It is also recommended that the hot-deck imputation method is applied within a category and not to the entire dataset.

4. Competitiveness Scoreboard – suitability as conceptual framework

The Competitiveness Scoreboard of the Fontagné report and the conceptual framework for the Competitiveness Index by the *Observatoire de la Compétitivité*, albeit exactly the same, they have different prerequisites. A scoreboard is meant to provide information on certain aspects of a phenomenon (benchmarking country performance along all the indicators included). On the other hand, a conceptual framework is meant to provide the basis for calculating a summary measure of a set of indicators, and thus issues of correlation, double counting, compensability and others enter into the discourse. Furthermore, the "making of" the Competitiveness Index demands a sensitive balance between simplifying competitiveness aspects and still providing sufficient detail to detect characteristic differences between the EU countries. Such conflicting demands could finish by producing a complex measure that is almost impossible to verify, particularly since competitiveness cannot be measured directly. It is therefore taken for granted that the Competitiveness Index by the *Observatoire de la Compétitivité* cannot be tested on the basis of ground truth.

Yet, in order to enable informed policy-making and to be useful as policy and analytical assessment tool, the Index needs to be assessed with regard to its validity and potential biases. The research question to be answered is:

- *Can the Scoreboard of Competitiveness of the Fontagné report be used as a conceptual framework for building an Index - what are the necessary changes?*

4.1. Correlation structure within a category

This analysis is composed of two parts. First, we study the correlation structure within each of the ten categories with a view to identify the degree of homogeneity of the information provided by the underlying indicators (this section). Second, we test whether the indicators are "statistically" assigned to the same category as conceptualised (next section).

For this first part of the analysis we use the raw data prior to directional transformation (missing values are not estimated). Hence, correlations are based on pairs of available data only.

In the ***Macroeconomic performance*** category (A), the correlations between the indicators are in most cases non significant (Table 7). The few statistically significant correlations are low to moderate in all cases (less than 0.65 in absolute terms). For example gross national income per capita (A1) has a moderate negative association to real growth rate of GDP (A2) and to diversification-entropy coefficient (A11), implying that high values of gross national income are associated to low growth rates and to low diversification, which is to a certain degree understandable, although all three indicators are expected to have the same direction (namely the higher the indicator's value the better for competitiveness, see "desired direction" column in Table 7). These correlations represent known trade-offs among economic variables. A similar trade-off appears between inflation rate (A5) and public debt (A7). Overall, this category is highly heterogeneous with most indicators exhibiting an autonomous behaviour. The latter is particularly evident for the real growth rate of GDP (A2), which has no statistically significant correlation to any of the indicators in the category. There are no specific recommendations to be made for this category, besides that some of the non significant indicators could be excluded, but this consideration will be made after having carried out also the second part of the analysis.

The ***Employment*** category (B), on the other hand, represents a highly homogeneous group of indicators with important overlap of information. Many of the indicators are correlated to each other and there are cases of strong collinearity involving employment rates for the total, female and male population. The highly homogenous nature of this

category is an artefact rather than a real world phenomenon. It is recommended that the two indicators on total employment rate (B1) and total employment rate of persons aged 55-64y (B4) are excluded from the category, given that the equivalent indicators for male and female rates are already included.

In the ***Productivity and Labour costs*** category (C), there is one case of strong collinearity between trends in total factor productivity (C1) and trends in apparent work productivity (C2). This strong correlation is also evident in all the previous years 2000-2007 (always greater than 0.85). It is recommended that these two indicators C1 and C2 are combined together; this implies assigning them 0.5 weight each when all other indicators in the category receive a weight of 1 each. The costs/revenue ratio in the banking sector (C5) has an entirely autonomous behaviour, not correlated to any of the four other indicators in the category.

The ***Market Operations*** category (D) is heterogeneous with few statistically significant correlations, but no strong collinearity or even important correlations. We note that one indicator composite basket of cellular telephone royalties (D6) has no statistically significant correlation to any of the eight remaining indicators in the category.

In the ***Institutional & Regularity Framework*** category (E) there are two highly collinear pairs of indicators, which could be combined so as to avoid double counting of information during the equal weighting aggregation. The pairs to be combined are: administration efficiency index (E6) with observance of the law index (E7), and degree of sophistication of online public services (E9) with public services fully available online (E10). Combining these indicators implies assigning them 0.5 weight each when all other indicators in the category receive a weight of 1.

In the ***Entrepreneurship*** (F) and ***Education & Training*** (G) category, half of the correlations are non-significant and half are low to moderate. There is little overlap of information and all indicators are associated to at least one of the other indicators in the category. Only volatility among companies (F4) in the Entrepreneurship category has no statistically significant correlation to any the other three indicators in the category.

The ***Knowledge Economy*** category (H) has several non-significant correlations and few significant but moderate correlations. There is in general little overlap of information between the 15 indicators. However, there are two highly correlated indicators − number of USPTO patents (H7) and number of OEB patents (H8) − that need to be combined (with 0.5 weight each when all other indicators in the category receive a weight of 1

each). Furthermore, three indicators exhibit an almost autonomous behaviour: portion of public research financed by the private sector (H3), percentage of sales allocated to the introduction of new products on the market (H4), and percentage of total employment in medium or high technology sectors (H15).

In ***Social Cohesion*** (I), the gini coefficient (I1) is strongly correlated to at persistent risk of poverty rate (I3), and to at-risk of poverty rate after social transfers (I2). In practice, these three indicators are dominating the category. Two indicators − life expectancy at birth (I4) and serious work accidents (I6)− have an entirely autonomous behaviour, not statistically significant associated to any of the indicators in the category; hence if the remaining three indicators are expected to have an impact, then the three collinear indicators I1, I2 and I3 should be combined.

The last category ***Environment*** (J) is also heterogeneous, characterised by many non-significant and just few significant but moderate correlations. We note here that two indicators −percentage of renewable energy sources (J4) and modal split in transportation-car users (J7) are not statistically associated to any of the indicators. There appears to exist a trade-off between the energy intensity of the economy (J6) and two indicators, namely total greenhouse gas emissions (J3) and municipal waste generated (J5). In fact, the more energy intensity economies have lower values in greenhouse gas emissions and less waste generated, which appears to be an odd outcome.

Table 7. Correlations within category

Category A: Macroeconomic performance

	Desired direction	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**
A1	+	-0.48	0.03	-0.38	-0.61	0.33	0.25	-0.40	-0.42	-0.43	-0.56	0.20
A2	+		0.37	-0.01	-0.06	0.00	-0.08	0.04	0.06	0.03	0.37	-0.23
A3	+			-0.23	-0.06	0.45	-0.22	-0.05	-0.14	-0.38	-0.34	0.08
A4	-				0.01	-0.44	0.21	-0.07	-0.13	0.34	0.22	-0.08
A5	-					-0.17	-0.55	0.65	0.54	0.47	0.31	-0.02
A6	+						-0.20	-0.28	-0.31	-0.43	-0.25	0.15
A7	-							-0.65	-0.40	-0.09	-0.24	-0.03
A8	+								0.51	0.31	0.32	0.03
A9	-									-0.06	0.11	-0.05
A10	-										0.36	0.44
A11	+											-0.39
A12	+											

Table 7. Correlations within category (cont.)

Category B: Employment

	Desired direction	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**
B1	+	0.82	0.94	0.75	0.66	0.71	-0.58	-0.56	0.60
B2	+		0.58	0.54	0.64	0.38	-0.57	-0.49	0.62
B3	+			0.76	0.57	0.79	-0.49	-0.51	0.48
B4	+				0.90	0.95	-0.27	-0.46	0.27
B5	+					0.72	-0.30	-0.36	0.19
B6	+						-0.20	-0.45	0.26
B7	-							0.45	-0.34
B8	-								-0.38
B9	+								

Category C: Productivity and Labour cost

	Desired direction	**C2**	**C3**	**C4**	**C5**
C1	+	0.96	-0.39	-0.70	0.39
C2	+		-0.51	-0.58	0.23
C3	+			-0.06	-0.01
C4	-				-0.31
C5	-				

Category D: Market Operations

	Desired direction	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
D2	-	0.41	0.42	0.33	0.37	0.44	0.12	-0.36	-0.21
D3	-		0.28	-0.14	0.14	0.01	-0.13	-0.48	-0.17
D4	-			-0.03	0.26	0.48	0.39	0.01	-0.09
D5	-				0.04	0.38	0.48	0.58	0.34
D6	-					0.30	-0.17	-0.03	-0.27
D7	-						0.22	-0.05	-0.19
D8	-							0.31	0.51
D9	+								0.32
D10	-								

Category E: Institutional & Regulatory Framework

	Desired direction	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**
E1	-	0.52	0.08	0.42	0.40	0.13	0.21	0.29	0.59	0.62
E2	-		0.60	0.31	0.39	0.47	0.40	0.38	0.54	0.48
E3	-			0.17	0.26	0.17	0.11	0.16	0.15	0.10
E4	-				0.81	-0.16	-0.20	-0.23	0.14	0.15
E5	-					-0.13	-0.15	-0.31	0.21	0.29
E6	+						0.96	0.46	0.55	0.42
E7	+							0.48	0.57	0.47
E8	+								0.45	0.34
E9	+									0.90
E10	+									

Table 7. Correlations within category (cont.)

Category F: Entrepreneurship

	Desired direction	**F2**	**F3**	**F4**
F1	+	0.47	0.08	0.55
F2	+		0.34	0.49
F3	+			0.20
F4	+			

Category G: Education & Training

	Desired direction	**G2**	**G4**	**G5**	**G6**
G1	-	-0.13	0.52	0.45	0.05
G2	+		0.29	0.18	-0.72
G4	+			0.70	-0.41
G5	+				-0.22
G6	-				

Category H: Knowledge Economy

	Desired direction	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**	**H11**	**H12**	**H13**	**H14**	**H15**
H1	+	-0.56	0.10	0.06	0.66	0.83	0.85	0.77	0.49	-0.19	0.73	0.42	0.34	0.58	0.22
H2	+		0.18	-0.05	-0.79	-0.50	-0.59	-0.65	-0.59	0.49	-0.73	-0.69	-0.48	-0.79	-0.19
H3	+			0.11	-0.16	-0.09	0.12	-0.05	-0.20	0.30	0.10	-0.54	0.09	-0.17	0.33
H4	+				0.20	0.22	0.23	0.25	-0.12	0.18	0.28	-0.11	-0.46	0.20	0.28
H5	+					0.74	0.76	0.72	0.41	-0.22	0.72	0.27	0.53	0.53	0.21
H6	+						0.81	0.70	0.44	-0.14	0.70	0.33	0.37	0.59	0.23
H7	+							0.92	0.38	-0.27	0.77	0.43	0.24	0.65	0.20
H8	+								0.41	-0.48	0.83	0.60	0.19	0.70	0.15
H9	+									-0.17	0.43	0.44	0.50	0.29	0.13
H10	+										-0.26	-0.50	-0.07	-0.28	0.40
H11	+											0.45	0.34	0.84	0.11
H12	+												0.10	0.67	-0.49
H13	+													0.17	-0.08
H14	+														-0.29
H15	+														

Category I: Social Cohesion

	Desired direction	**I2**	**I3**	**I4**	**I5**	**I6**
I1	-	0.88	0.90	-0.22	-0.02	0.30
I2	-		0.84	-0.21	-0.15	0.21
I3	-			0.00	-0.55	-0.25
I4	+				-0.13	-0.20
I5	-					0.26
I6	-					

Table 7. Correlations within category (cont.)

Category J: Environment

	Desired direction	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**
J1	+	0.45	0.29	-0.13	0.07	-0.12	-0.34
J2	+		0.06	0.35	0.00	-0.08	-0.29
J3	-			-0.01	0.59	-0.61	0.07
J4	+				-0.03	-0.21	0.12
J5	-					-0.66	0.00
J6	-						-0.33
J7	-						

Notes:
1. Pearson correlations coefficients are calculated using raw data prior to directional adjustment (pairwise deletion of missing data)
2. Correlation coefficients lower than 0.4 (absolute terms) are not statistically significant at 95%.
3. Significant correlations, greater than 0.4 (absolute value) are marked in light grey.
4. Important correlations, greater than 0.7 (absolute value) are marked in dark grey.
5. Full indicator names are given in Table 1.

4.2. Cross-correlations between indicators and categories

In the second part of the analysis, we test whether the indicators are "statistically" assigned to the same category as conceptualised. Factor analysis is a classical tool for this type of analysis. However, due to the low ratio of (number of countries)/(number of indicators) within many of the categories, the common rule of thumb requiring 5:1 ratio (Bryant & Yarnold, 1995; Nunnaly, 1978, Gorsuch, 1983) is not satisfied. At the same time, for eight of the ten categories the KMO (Kaiser-Meyer-Olkin) statistic is close to 0.5 or less, which indicates that the correlation matrix in those categories is not suitable for factor analysis. The KMO statistic was acceptable only for the Knowledge Economy (H) and the Social Cohesion (I) category (KMO close to 0.7 in both cases).

We opt for simpler, nevertheless informative approaches, to study the statistical grouping of indicators by means of cross-correlation analysis between the indicators and the categories. Intuitively, one would expect that an indicator is more correlated to its own category than to other categories. For this part of the analysis, since we need to calculate country scores in the categories and in the Index, we use winsorised data, after estimating missing data with the hot-deck method (Manhattan distance), and scaling them using the min-max approach with directional adjustment.

Overall, the expectation that the indicators are more correlated to their own category than to any other category of competitiveness is confirmed and furthermore all statistically significant correlations have the expected sign (Table 8). However, there are many indicators, which although included in the framework do not affect the country scores in their own category and do not seem to belong either to any of the other categories of competitiveness. We will discuss them next.

Table 8. Cross-correlations between indicators and Categories

	Desired direction	A	B	C	D	E	F	G	H	I	J
A1	+	0.41	0.48	0.12	0.21	0.53	-0.48	0.27	0.67	0.34	0.05
A2	+	0.27	-0.36	0.37	-0.37	-0.49	0.32	-0.04	-0.26	0.21	-0.08
A3	+	0.61	-0.20	-0.17	-0.15	-0.15	-0.17	-0.07	0.02	0.41	-0.19
A4	-	-0.59	-0.53	0.12	-0.13	-0.29	0.17	-0.25	-0.19	-0.17	0.16
A5	-	-0.29	-0.04	-0.46	0.13	-0.17	0.28	0.05	-0.49	-0.53	-0.15
A6	+	0.73	0.43	-0.09	0.06	0.01	-0.58	0.43	0.56	0.50	0.16
A7	-	-0.37	-0.27	0.39	-0.01	-0.32	-0.03	-0.33	0.07	0.26	0.06
A8	+	0.04	-0.03	-0.54	0.09	0.08	0.42	0.04	-0.50	-0.48	-0.19
A9	-	-0.28	0.01	-0.24	0.37	0.00	0.32	-0.17	-0.46	-0.59	-0.17
A10	-	-0.36	-0.42	-0.09	-0.41	0.01	0.04	-0.05	-0.32	-0.06	0.09
A11	+	-0.18	-0.16	-0.04	-0.16	-0.26	0.24	0.15	-0.20	-0.18	0.29
A12	+	0.21	-0.23	-0.24	-0.10	0.16	-0.17	-0.11	0.05	0.20	-0.09
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
B1	+	0.39	0.95	0.02	0.27	0.52	-0.40	0.58	0.60	0.07	0.13
B2	+	0.30	0.81	0.22	0.19	0.55	-0.33	0.25	0.44	0.18	0.02
B3	+	0.38	0.88	-0.10	0.28	0.41	-0.36	0.68	0.59	-0.03	0.17
B4	+	0.05	0.86	-0.05	0.34	0.41	-0.03	0.47	0.32	-0.36	0.05
B5	+	-0.01	0.79	0.15	0.15	0.37	0.10	0.36	0.13	-0.33	-0.02
B6	+	0.06	0.80	-0.19	0.43	0.36	-0.11	0.49	0.40	-0.36	0.09
B7	-	-0.41	-0.60	0.10	0.04	-0.42	0.22	-0.24	-0.17	-0.10	0.28
B8	-	-0.37	-0.66	0.15	-0.36	-0.44	0.19	-0.36	-0.24	0.09	0.08
B9	+	0.33	0.58	0.19	0.39	0.32	-0.40	0.28	0.72	0.32	0.17
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
C1	+	-0.34	-0.21	0.60	-0.31	-0.44	0.16	-0.06	-0.21	0.15	0.07
C2	+	-0.08	-0.31	0.56	-0.29	-0.42	0.43	-0.05	-0.26	0.04	0.03
C3	+	0.31	0.39	0.18	0.32	0.41	-0.56	0.27	0.75	0.39	0.15
C4	-	0.01	-0.02	-0.77	0.17	0.26	-0.04	0.03	-0.15	-0.31	-0.13
C5	-	0.22	0.00	-0.18	0.18	-0.37	0.14	0.03	0.11	0.18	0.09
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
D2	-	-0.03	-0.24	0.37	-0.66	0.10	0.17	-0.30	-0.25	0.20	-0.21
D3	-	0.08	-0.10	0.14	-0.37	0.21	-0.23	-0.08	0.16	0.36	0.09
D4	-	0.37	-0.17	0.04	-0.76	0.09	0.04	-0.16	-0.21	0.31	-0.13
D5	-	-0.33	-0.28	-0.01	-0.51	-0.30	0.16	0.11	-0.44	-0.28	-0.05

D6	-	-0.32	-0.16	0.22	-0.32	0.23	-0.07	-0.27	-0.17	-0.02	-0.06
D7	-	0.19	0.03	0.09	-0.72	0.17	-0.09	0.09	-0.21	0.07	-0.15
D8	-	0.28	-0.25	0.01	-0.58	-0.26	0.25	0.10	-0.14	0.13	0.02
D9	+	-0.22	-0.03	-0.50	0.05	-0.21	0.34	0.15	-0.45	-0.49	-0.06
D10	-	-0.11	-0.13	-0.24	-0.12	-0.29	0.27	-0.15	-0.15	-0.01	0.08
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
E1	-	-0.06	-0.08	0.33	0.30	0.03	-0.50	-0.17	0.51	0.44	0.29
E2	-	0.33	0.31	0.11	0.35	0.03	-0.46	0.27	0.66	0.52	0.32
E3	-	0.15	0.20	-0.12	0.29	-0.22	-0.37	0.41	0.45	0.34	0.39
E4	-	0.02	-0.17	0.02	-0.16	-0.51	-0.07	-0.03	-0.11	0.17	0.03
E5	-	0.01	-0.16	0.23	-0.06	-0.50	-0.01	-0.06	0.02	0.25	0.11
E6	+	0.50	0.59	-0.24	0.23	0.67	-0.31	0.22	0.46	0.18	0.03
E7	+	0.40	0.51	-0.23	0.21	0.73	-0.29	0.13	0.45	0.17	0.01
E8	+	0.30	0.62	0.13	0.25	0.65	-0.54	0.38	0.71	0.23	0.03
E9	+	0.09	0.31	0.30	0.09	0.50	-0.41	-0.08	0.51	0.40	0.25
E10	+	-0.06	0.22	0.33	0.04	0.42	-0.27	-0.17	0.45	0.25	0.30
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
F1	+	-0.44	-0.19	-0.16	0.05	-0.11	0.88	-0.46	-0.64	-0.69	-0.47
F2	+	-0.21	-0.46	0.00	-0.07	-0.54	0.73	-0.39	-0.61	-0.24	-0.16
F3	+	0.01	-0.16	0.01	-0.02	-0.06	0.35	0.05	-0.05	-0.27	0.24
F4	+	-0.12	0.01	-0.12	-0.22	0.29	0.75	-0.49	-0.48	-0.47	-0.52
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
G1	-	0.47	0.22	0.07	0.06	0.42	-0.47	0.01	0.48	0.46	0.01
G2	+	0.23	0.17	0.10	-0.05	-0.18	-0.23	0.79	0.21	0.08	0.34
G4	+	0.39	0.62	0.09	0.26	0.35	-0.65	0.70	0.72	0.22	0.08
G5	+	0.39	0.73	0.12	0.35	0.39	-0.60	0.61	0.78	0.33	0.39
G6	-	-0.41	-0.18	0.04	0.09	0.15	0.33	-0.82	-0.27	-0.16	-0.20
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
H1	+	0.34	0.54	0.30	0.31	0.34	-0.50	0.48	0.89	0.35	0.46
H2	+	-0.23	-0.15	-0.17	-0.18	-0.40	0.65	-0.09	-0.63	-0.56	-0.11
H3	+	0.03	-0.18	-0.14	-0.07	-0.31	0.15	0.27	-0.05	-0.14	0.01
H4	+	0.23	0.05	0.23	0.06	-0.04	-0.19	0.23	0.38	0.23	0.30
H5	+	0.27	0.36	0.10	0.40	0.20	-0.74	0.41	0.81	0.49	0.29
H6	+	0.29	0.60	0.26	0.37	0.21	-0.59	0.58	0.86	0.42	0.46
H7	+	0.46	0.53	0.13	0.31	0.21	-0.54	0.53	0.91	0.40	0.28
H8	+	0.52	0.46	0.06	0.29	0.25	-0.61	0.40	0.86	0.49	0.27
H9	+	0.13	0.16	0.28	-0.07	0.40	-0.43	-0.10	0.50	0.43	0.15
H10	+	-0.30	-0.25	0.09	-0.25	-0.34	0.33	0.10	-0.21	-0.24	0.12
H11	+	0.42	0.54	0.11	0.20	0.47	-0.72	0.47	0.86	0.44	0.23
H12	+	0.32	0.32	0.07	0.28	0.43	-0.39	-0.04	0.50	0.29	0.10
H13	+	0.03	0.22	0.09	0.18	0.18	-0.58	0.12	0.35	0.28	-0.08
H14	+	0.47	0.60	0.02	0.42	0.58	-0.41	0.36	0.75	0.25	0.06
H15	+	0.03	-0.22	0.29	-0.27	-0.18	-0.34	0.23	0.35	0.51	0.57
	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
I1	-	-0.61	0.02	-0.20	0.23	0.07	0.64	-0.39	-0.47	-0.89	-0.35
I2	-	-0.63	-0.15	-0.23	0.27	-0.02	0.65	-0.37	-0.51	-0.84	-0.30

I3	-	-0.47	-0.19	-0.30	0.25	-0.02	0.77	-0.49	-0.53	-0.78	-0.35
I4	+	0.25	0.20	0.42	0.04	0.26	-0.31	-0.08	0.50	0.52	0.16
I5	-	0.26	0.60	0.13	0.04	0.27	-0.21	0.58	0.32	-0.20	0.03
I6	-	0.00	0.47	-0.23	0.15	0.49	0.06	0.24	-0.02	-0.49	-0.14

	Desired direction	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
J1	+	-0.14	-0.22	0.25	-0.16	-0.06	-0.05	-0.22	-0.01	0.25	0.48
J2	+	0.13	0.24	0.19	0.03	0.10	-0.39	0.41	0.36	0.27	0.76
J3	-	0.09	0.06	0.33	-0.31	0.26	0.01	-0.37	-0.03	0.26	-0.23
J4	+	0.07	0.35	-0.06	0.19	0.08	-0.23	0.24	0.33	0.14	0.56
J5	-	0.29	0.43	0.00	0.13	0.60	-0.17	-0.05	0.31	0.17	-0.30
J6	-	-0.02	-0.30	-0.22	-0.14	-0.37	0.34	0.01	-0.48	-0.29	-0.03
J7	-	-0.31	0.18	-0.08	0.27	-0.03	0.16	-0.06	-0.17	-0.42	-0.36

Notes:
1. Numbers express Pearson correlation coefficients.
2. For the purposes of this analysis, category scores were calculated using winsorised data for seven indicators (see Section 3.2), after estimating missing data with the hot-deck method (Manhattan distance, Section 3.4), and scaling them using the min-max approach with directional adjustment.
3. Correlation coefficients lower than 0.4 (absolute terms) are not statistically significant at 95%.
4. Significant correlations, greater than 0.4 (absolute value) are marked in light grey.
5. Important correlations, greater than 0.7 (absolute value) are marked in dark grey.
6. Full indicator names are given in Table 1.

4.3. Competitiveness Index –what it is and it is not about

Weak associations with competitiveness

The inclusion of an indicator in a conceptual framework provides no guarantee that the indicator will affect the final Index results. This is an important remark to make as this is a common misconception among stakeholders that wish to have a saying on an Index by suggesting which indicators to include.

The Competitiveness dataset composed of 82 indicators in 2008 reveals that not all that is included in the framework has an impact on the results. Table 9 lists twenty five indicators in the dataset that are not statistically significant correlated either to their own category or to the final Index. These include for example the real growth rate of GDP (A2), the gross fixed capital formation (A8), costs/revenue ratio in the banking sector (C5), total state aid (D10), corporate taxes (E1), portion of public research published by the private sector (H3), total greenhouse gas emissions (J3), and municipal waste generated (J5).

Table 9. Weak correlations between the Index or category and the indicators

Indicator	*Category*	*INDEX*
	A	
A2 Real growth rate of GDP	0.27	-0.11
A5 Inflation rate (%)	-0.29	-0.37
A7 Public debt as a % of GDP	-0.37	-0.13
A8 Gross fixed capital formation- public administration	0.04	-0.23
A9 Terms of trade	-0.28	-0.27
A11 Diversification – entropy coefficient	-0.18	-0.12
A12 FDI inflows/outflows	0.21	-0.11
	C	
C5 Costs / Revenue ratio in the banking sector	-0.18	0.13
	D	
D3 Price of gas (ex-VAT) - industrial users	-0.37	0.03
D6 Composite basket of cellular telephone royalties (ex-VAT)	-0.32	-0.25
D9 Public markets – value of public markets using open procedure procurement	0.05	-0.30
D10 Total of State aid as a % of GDP (excluding horizontal objectives)	-0.12	-0.17
	E	
E1 Corporate taxes	0.03	0.20
E3 Standard VAT rate	-0.22	0.38
	F	
F3 Net change in number of companies (start-up rate less close-down rate)	0.35	0.01
	G	
G1 Annual cost per student in public educational facilities	0.01	0.38
	H	
H3 Portion of public research financed by the private sector	-0.05	-0.10
H4 Percentage of sales allocated to the introduction of new products on the market (new or significantly improved products)	0.38	0.33
H10 Investment in public telecommunications as a percentage of gross fixed capital formation	-0.21	-0.22
H13 Percentage of households that have broad band Internet access	0.35	0.17
H15 Percentage of total employment in medium or high technology sectors	0.35	0.18
	J	
J3 Total greenhouse gas emissions	-0.23	0.02
J5 Volume of municipal waste generated	-0.30	0.36
J6 Energy intensity of the economy	-0.03	-0.36
J7 Modal split in transportation choice-percentage of car users as transportation method	-0.36	-0.15

Notes: 1. Numbers express Pearson correlation coefficients.
2. For the purposes of this analysis, category scores were calculated using winsorised data for seven indicators (see Section 3.2), after estimating missing data with the hot-deck method (Manhattan distance, Section 3.4), and scaling them using the min-max approach with directional adjustment.

The random association between the Index (and category) scores and these twenty five indicators should not be interpreted as if these indicators do not describe important aspects of competitiveness. For example, the indicator FDI inflows/outflows is often considered to be a key governmental objective within the context of competitiveness. However, these random associations imply that even if some EU countries improve their relative performance in terms of FDI inflows/outflows, this improvement will not lead to an overall improvement in the Macroeconomic Performance score or in their final Index score. Some authors (e.g. Booysen, 2002) recommend that a weak (practically random) correlation between an underlying indicator and an index should result in the exclusion of that indicator from the conceptual framework. An eventual revision of the conceptual framework of competitiveness could take this into consideration and eventually streamline the 82 indicators into a smaller number of indicators. The advantage of such a streamlining exercise will be that all indicators included in the revised framework will play an important role in the country classification and will also be easier to communicate to the audience that "all that is included in the Index matters". Prior to doing so, however, suggestions on combining or eliminating some indicators, offered earlier in this Chapter, should be considered.

Drivers of Competitiveness in the selected framework

The indicators that are strongly correlated with the final index have the expected sign (same direction) both with respect to the Index and to the respective category (Table 10). Among the drivers of competitiveness, in the current conceptual framework, are: employment rates for male and female (B2, B3), lifelong learning (G5), internal R&D expenditure (H1), scientific publications (H6) and number of patents (H7, H8). Improving national performance at any of those indicators boosts the overall national competitiveness score.

Table 10. Strong correlations between the Index or category and the indicators

Indicator	*Desired direction*	*Category*	*INDEX*
		A	
A6 Public balance as a % of GDP	+	0.73	0.51
		B	
B1 Employment rate	+	0.95	0.80
B2 Employment rate (male)	+	0.81	0.66
B3 Employment rate (female)	+	0.88	0.74
B4 Employment rate of persons 55y -64y (total)	+	0.86	0.56
B6 Employment rate of persons 55y-64y (female)	+	0.80	0.53
		E	
E6 Administration efficiency index	+	0.67	0.57
E7 Observance of the law index	+	0.73	0.50
E8 Regulatory quality index	+	0.65	0.66
		G	
G4 Percentage of human resources in scientific and technological fields as a % of total employment	+	0.70	0.66
G5 Lifelong learning (participation of adults in training and teaching programs)	+	0.61	0.84
		H	
H1. Internal R&D expenditure	+	0.89	0.83
H5 Number of researchers per 1,000 employed persons	+	0.81	0.59
H6 Scientific publications per million inhabitants	+	0.86	0.84
H7 Number of patents USPTO per million inhab.	+	0.91	0.77
H8 Number of patents OEB per million inhabitants	+	0.86	0.70
H11 Percentage of households that have Internet access at home	+	0.86	0.70
H14 Number of secure web servers per 100,000 inhabitants	+	0.75	0.75

Notes:
1. Numbers express Pearson correlation coefficients.
2. For the purposes of this analysis, category scores were calculated using winsorised data for seven indicators (see Section 3.2), after estimating missing data with the hot-deck method (Manhattan distance, Section 3.4), and scaling them using the min-max approach with directional adjustment.

Lisbon indicators and Competitiveness

Next we summarise how the twelve Lisbon Indicators affect the overall Competitiveness classification of the EU 27 countries (Table 11). Six indicators, including employment rates (total, men, women), employment rates for the age group 55-64y (total, women) together with the internal R&D expenditure are driving the overall results. Employment rate for men aged 55-64y and the long-term unemployment rate have a significant

(moderate) impact, whilst the remaining indicators on real growth rate, total greenhouse gas emissions and energy intensity of the economy are not statistically significant. The impact of at risk of poverty rate after social transfers, though significant, is very low. These results are, in part, encouraging as they suggest that tracking the trends on the Lisbon indicators can offer a hint about the direction of national competitiveness in the EU. However, if all Lisbon indicators are meant to be important in determining the competitiveness level of the EU countries, then some modifications to the conceptual framework are needed to include these impacts too. It is evident, that simply placing a Lisbon indicator in the framework does not provide any guarantee that the indicator will have a significant impact on the results.

Table 11. Lisbon indicators - association to the Competitiveness Index

A2 Real growth rate	Not statistically significant
B1 Employment rate (total)	**Driver**
B2 Employment rate (Men)	**Driver**
B3 Employment rate (Women)	**Driver**
B4 Employment rate 55-64y (total)	**Driver**
B5 Employment rate 55-64y (men)	*Significant (moderate) impact*
B6 Employment rate 55-64y (women)	**Driver**
B8 Long-term un employment rate	*Significant(moderate) impact*
H1 Internal R%D expenditure	**Driver**
I2 At risk of poverty rate after social transfers	Statistically significant (but low)
J3 Total greenhouse gas emissions	Not statistically significant
J6 Energy intensity of the economy	Not statistically significant

4.4. Impact of categories on the final Index

Correlation analysis

The ten categories of the conceptual framework account for different aspects of competitiveness with very little overlap of information between them. This is evident in the many non-significant correlations between the ten Categories (Table 12)[7]. Some significant, albeit moderate, correlations are found between Employment (B) and

[7] Recall that for the dataset of the 27 EU Member States, a correlation coefficient is significant if it greaten than 0.4. Below this threshold, all coefficients indicate random associations between the categories/indicators.

Institutional & Regulatory Framework (E), between Employment and Education & Training (G), between Education & Training and the Knowldege Economy (H) and finally between the Knowledge Economy and Social Cohesion (I). On the other hand, Productive and Labour Costs (C) and Market Operations (D) are randomly associated to all other categories and to the overall index. Furthermore, Social Cohesion (I) and Environment (J) appear to have no statistically significant impact to the final Index.

It is peculiar that the Entrepreneurship category (F) is negatively associated to three categories − Education & Training (G), Knowledge Economy (H), and Social Cohesion (I). The association of Entrepreneurship to the remaining six categories is random. Intuitively, one would have expected that all correlations between categories are statistically significant and positive, namely that all categories point to the same direction (recall that all indicators were transformed into the higher the better direction). The results, instead suggest, that with the current framework, there is a trade-off between competitiveness and entrepreneurship and that the more competitive countries are those with lower entrepreneurship scores. If this conclusion sounds unfounded, then the entrepreneurship category and the underlying indicators may need to be revised. By revising that category, it might be that the impact of the other categories such as Social Cohesion (I) becomes more evident.

The practically random correlations between most of the categories and with respect to the final index bring up an important issue: *should the Competitiveness concept be measured by a single number or better presented as a thematic indicator of ten composite indicators (= categories)?*

As a rule of thumb based on our experience gained through auditing other composite indicators, Pearson correlation coefficients in the range 0.4 to 0.8 among the main dimensions of an Index are a positive result as they suggest that the main dimensions are significantly and positively associated to each other and with respect to the final Index, yet not highly collinear. To make the opposite case clear, imagine what happens when taking ten random variables with little or no correlation between them and calculating their average. The resulting index is of dubious information content.

It is suggested, than if upon revision of the conceptual framework, this problem persists − that is the categories are practically not associated to each other or to the overall index− then it would be more appropriate to focus on the classification of the EU

countries along the ten categories instead of the final index[8]. The *Observatoire de la Compétitivité* in its report 2008 *Bilan Compétitivité* is in fact discussing thoroughly the national performance of the 27 EU Member States at the category level. The construction of the Index was a secondary objective of the report.

The community of composite indicator developers may find appealing this example on EU competitiveness, as it suggests that a final composite indicator should not be seen as a goal per se. It is sometimes preferred to stop the aggregation procedure at the main dimensions level.

Table 12. Pearson correlation coefficients between the Categories

	B. Employment	C. Productivity and Labour Costs	D. Market Operations	E. Institutional & Regulatory Framework	F. Entrepreneurship	G. Education & Training	H. Knowledge Economy	I. Social Cohesion	J. Environment	Competitiveness Index
A. Macroeconomic performance	0.31	-0.11	-0.07	0.21	-0.31	0.37	0.43	0.49	-0.02	0.54
B. Employment		0.00	0.33	0.54	-0.27	0.53	0.50	-0.09	0.03	0.76
C. Productivity and Labour Costs			-0.23	-0.07	-0.11	0.08	0.23	0.34	0.14	0.29
D. Market Operations				0.03	-0.09	0.15	0.28	-0.24	0.08	0.33
E. Institutional & Regulatory Framework					-0.13	0.04	0.29	-0.09	-0.11	0.41
F. Entrepreneurship						-0.51	-0.68	-0.63	-0.40	-0.45
G. Education & Training							0.57	0.15	0.34	0.66
H. Knowledge Economy								0.50	0.43	0.83
I. Social Cohesion									0.35	0.38
J. Environment										0.38
Competitiveness Index										

Notes:
1. Numbers express Pearson correlation coefficients.
2. For the purposes of this analysis, category scores were calculated using winsorised data for seven indicators (see Section 3.2), after estimating missing data with the hot-deck method (Manhattan distance, Section 3.4), and scaling them using the min-max approach with directional adjustment.
3. Correlation coefficients lower than 0.4 (absolute terms) are not statistically significant at 95%.
4. Significant correlations, greater than 0.4 (absolute value) are marked in light grey.
5. Important correlations, greater than 0.7 (absolute value) are marked in dark grey.

[8] A Thematic Indicator as opposed to a final composite indicator was developed for the Multidimensional Poverty Assessment Tool for similar reasons.

Effective versus nominal weights

Another approach to assess the contribution of a category $\mathbf{X}_i$ $(i = 1,...,10)$ to the competitiveness classification follows directly from the formula for the variance of a sum. If category scores are multiplied by the corresponding weights w_i $(i = 1,...,10)$, and σ_i^2 is the variance associated with each category $\mathbf{X}_i$, then the variance of the Index scores is given by

$$\sigma^2 = \sum_{i=1}^{10} w_i^2 \sigma_i^2 + \sum_{i=1, i \neq k}^{10} \sum_{k=1}^{10} w_i w_k \operatorname{cov}(X_i, X_k) \tag{6}$$

While the w_i's constitute the 'nominal weights', the 'effective weight' of each indicator, according to Stanley and Wang (1968), is given by the ratio

$$E_i = \frac{w_i^2 \sigma_i^2 + \sum_{i=1, k \neq i}^{10} w_i w_k \operatorname{cov}(X_i, X_k)}{\sigma^2} \tag{7}$$

In other words, the effective weight of each category represents that part of the variance of the Index scores that can be attributed to the relevant category. Equation (7) shows that although the nominal weights do influence the effective weights, they are generally not proportional to them.

Table 13 presents the nominal and the effective weights for the ten categories. Overall, there is no strong dominance issue, but the effective weights are not always consistent with the nominal weights assigned to the categories. In fact, despite the equal weights assigned to all ten categories, the effective weights suggest that the most influential categories in discriminating the performance of the EU countries are Employment (B), Knowledge Economy (H), and Education & Training (G), followed by Social Cohesion (I). The explanation, as shown theoretically above, lays in the different variances of the categories scores and/or their correlations. This analysis further confirms that when taking into account the weights and the correlation structure, the Entrepreneurship category (F) moves into the opposite direction from the final Index.

The least influential Categories are Productivity and Labour Costs (C), Environment (J), and Market Operations (D).

A way to deal with this inconcistency between nominal and effective weights is to re-scale the category scores using the min-max approach and then average them. Another way, eventually in addition to the previous one, could be to adjust the nominal weights so that the effective weights of the ten categories are equal. Yet, priority should be given to revising the framework (combining or excluding some indicators as already discussed) and dealing with the issue of the trade-off between Entrepreneurship and Competitiveness (through the trade-offs with Education & Training, Knowledge Economy, Social Cohesion, Environment).

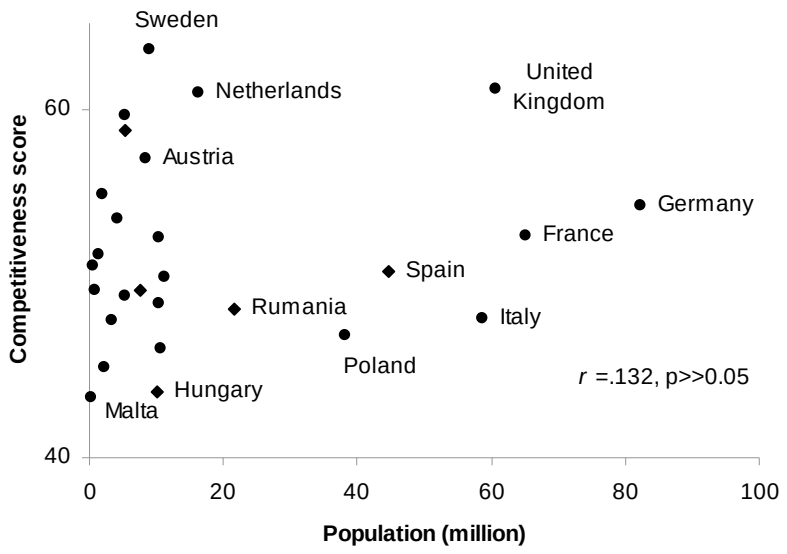
Table 13. Nominal and effective weights of the categories of Competitiveness

Competitiveness category	***Nominal weights***	***Effective weights***
A. Macroeconomic performance	0.100	0.081
B. Employment	0.100	0.270
C. Productivity & Labour Cost	0.100	0.056
D. Market Operations	0.101	0.080
E. Institutional and Regulatory Framework	0.100	0.086
F. Entrepreneurship	0.100	-0.163
G. Education & Training	0.100	0.186
H. Knowledge Economy	0.098	0.206
I. Social Cohesion	0.101	0.130
J. Environment	0.100	0.067

4.5 Competitiveness and population size

A question on whether a country's population size can bias competitiveness can be raised. In the 27 EU countries, the 2008 Index results show that there is no clear pattern as to whether population size has a positive or negative impact on competitiveness (Figure 2). The association between the Index scores and population is not statistically significant ($r = 0.132, p >> 0.05$), which implies that the Index is not biased with respect to population size or to the land area. Neither are any of the ten categories biased against land area or population size.

Figure 2. Competitiveness Index vs. Population Size



5. Uncertainty and sensitivity analysis

The creativity evident in the work of composite indicator developers is not only a response to the multiple demands of the user/stakeholder community but also the result of disagreement within the research community on which indicators influence a particular phenomenon, and by how much. Notwithstanding recent attempts to establish best practice in composite indicator construction (OECD, 2008), "there is no recipe for building composite indicators that is at the same time universally applicable and sufficiently detailed" (Cherchye et al., 2008). This may be due in part to the ambivalent role of composite indicators in both analysis and advocacy (Saltelli, 2007). As the boundaries between the two functions are often blurred, controversy may be unavoidable when discussing these measures.

When building an index to measure competitiveness in the European Union, it is necessary to take stock of existing methodologies in order to avoid eventual skewness in the assessment and decision-making. By acknowledging the variety of methodological assumptions involved in the development of an index, one can determine whether the main results change substantially when the main assumptions are varied over a reasonable range of possibilities (Saisana *et al.*, 2005; Saltelli et al., 2008). The advantages offered by considering different scenarios to build the Index could be: to gauge the

robustness of the Index scores and ranks, to increase its transparency, to identify those countries whose performance improves or deteriorates under certain assumptions, and to help frame the debate on the use of the results for policy making.

The main question to be addressed here is:

- *What scenarios could have been used to build the European Union Competitiveness Index and how do the results of these scenarios compare to the baseline scenario?*

We show below how uncertainty analysis (UA) can contribute to such a reflection. UA involves assessing the impact of alternative models on the country ranks. Each model is a different composite indicator in which the choice of normalization, imputation, weights and aggregation method has been varied within a plausible range. This approach helps to avert the criticism frequently dealt to composite measures or rankings, namely that they are presented as if they had been calculated under conditions of certainty (while this is rarely the case) and then taken at face value by end-users (Saisana et al., 2005).

The objective of UA is not to establish the truth or to verify whether the EU Competitiveness Index is a legitimate model, but rather to test whether the ranking itself and/or its associated inferences are robust or volatile with respect to changes in the methodological assumptions within a plausible and legitimate range. Uncertainty (or robustness) analysis as described by the OECD (2008) has been already used for the assessment of several composite indicators, such as the Multi-dimensional Poverty Assessment Tool (Saisana and Saltelli, 2010), the Composite Learning Index (Saisana, 2008), the Environmental Performance Index (Saisana and Saltelli, 2010), the Alcohol Policy Index (Brand et al., 2007), the Knowledge Economy Index (Saisana and Munda, 2008), the Index of African Governance (Saisana *et al.*,2009) and the University Ranking Systems (Saisana and D'Hombres, 2008).

Furthermore, this part of the analysis aims at identifying those countries for which the EU competitiveness ranking is robust as well as those for which it is not. For the first group, policy signals derived from the EU Competitiveness Index can be taken with the confidence that changes in the methodology would have a negligible effect on the country's measured performance. For the latter a more cautious approach is advised before translating the EU competitiveness rank into policy actions or naming-shaming narratives.

5.1 Multi-modelling approach

A multi-modelling approach was applied in the present work for the purpose of robustness analysis. It consists of exploring, via a saturated sampling, plausible combinations of the main assumptions needed to build the index:

- measurement error of the raw data,
- imputation for missing values,
- normalisation method,
- aggregation function at the category level, and
- exclusion of a category.

(a) Measurement error: It is reasonable to assume that the raw data are not flawless and that despite efforts to guarantee the most reliable sources for them, errors may still be present. To account for this, we have added a normally distributed random error term to the raw data with a mean zero and a standard deviation that is one fifth, or half, or two-thirds or equal, or 1.25, or 1.5 or twice the observed standard deviation for each indicator. Several alternative datasets that include error in some of the data values are generated to this end.

(b) Imputation of missing data: The Observatoire de la Compétitivité opted not to impute missing data, but instead to calculate the category and final Index scores per country by averaging the available data values. An alternative approach known as mean substitution was also considered by the team, but not used after all. As discussed in Chapter 3, both approaches have notable shortcomings. Here, we have used the hot-deck method based on Manhattan distance. Hence, in some of the scenarios hot-deck imputation is used, while in other scenarios the original approach to average available indicator values is used.

(c) Normalisation of the raw data: To keep things as simple as possible, the Observatoire de la Compétitivité used the min-max scaling method to normalise the raw data. Another legitimate approach would have been the standardisation method (subtracting the mean and dividing by the standard deviation), which we tested here as an alternative.

(e) Assumption on the aggregation function: The original ranking is built using a weighted arithmetic average, hence a linear aggregation rule (Eq. 8) of the indicators. Decision theory practitioners have challenged aggregations based on additive models because of inherent theoretical inconsistencies (Munda, 2008) and the fully compensatory nature of

linear aggregation, in which an x% increase in one indicator can offset an y% decrease in another, where y depends from the ratio of the weights of the two variables. This is the reason why practitioners call weights in linear aggregation 'trade-off coefficients', not to be confused with measures of importance.

We would argue that the calculation of the ten Competitiveness categories as an arithmetic average of the indicators has the advantage of "compensating" for eventual inconsistencies in the data. At the second level of aggregation, instead, namely from the categories into the final Index, the use of a less compensatory aggregation function would be more advantageous, as it would imply that a country should place more effort in improving itself in those categories where it is relatively weak. To this end, we applied two alternative aggregation functions: a geometric weighted average (Eq. 9) and a multi-criteria method (Eq. 10)[9].

In the case of the geometric averaging, we shifted slightly the categories scores to above 1.00 to allow for the proper use of the geometric aggregation. From the multi-criteria literature, we selected a method suggested by Brand et al. (2007) because it can deal with a large number of countries and it can also deal with eventual ties in the category scores.

Weighted Arithmetic Average score: $$y_j = \sum_{i=1}^{n} w_i \cdot x_{ij} \tag{8}$$

Weighted Geometric Average score: $$y_j = \prod_{i=1}^{n} x_{ij}^{w_i} \tag{9}$$

Borda adjusted score: $$y_j = \sum_{i=1}^{n} (m_{ij} + \frac{k_{ij}}{2}) \cdot w_i \tag{10}$$

y_j: composite indicator score for country j, w_i: weight attached to policy category i, x_{ij}: score for country j on policy category i, m_{ij}: number of countries that have weaker performance than country j relative to policy category i; k_{ij}: number of countries with equivalent performance to country j relative to policy category i.

(f) Assumption on the categories: We have either kept all ten categories or in some cases excluded one at a time. This statistical procedure is a tool to test the robustness of

[9] Both geometric aggregation and the Borda method applied here are less compensatory than linear weighting. For details see OECD (2008).

inference and should not be seen as a disturbance of the framework. In fact it makes it possible to assess the impact of assigning a zero weight to a category, combined with the other assumptions (e.g. on the weighting method and aggregation rule). Eliminating a category from the framework can also be seen as "tuning" the ranking in favour of countries which have a comparative disadvantage on that aspect (Grupp and Mogee, 2004).

The combinations of these assumptions are translated into a set of roughly $N \approx 1000$ simulations in a Monte Carlo framework. The composite index is then evaluated N times, and the Index scores and ranks obtained are associated with the corresponding draws of assumptions to appraise their influence. Note that in this part of the analysis no winsorization was applied (see Chapter 3).

5.2 Uncertainty analysis results

The results shown in Table 14 are the frequencies of a country's rank in the overall EU Competitiveness Index calculated across all 1000 scenarios. Such a frequency matrix synthesizes the ranking while making the uncertainty explicit. It is beyond doubt that Sweden is the most competitive country in the EU. The UK, Netherlands, Finland and Denmark are all top five countries, but assigning a specific rank to any of those countries would be too bold and unsupported by the uncertainties. Particularly uncertain is the position of Greece: in 25% of the scenarios the country is ranked somewhere between the 15th and 17th position, but in the remaining 75% of the scenarios, Greece is at the 22nd position or lower. The rank of Luxembourg is also very sensitive to the assumptions. Towards the end of the classification, Malta's performance is among the bottom five countries, but certainly not last as in the baseline ranking.

Table 14. Frequency matrix of a country's rank in the Competitiveness Index

Country	Baseline	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Sweden	1	97																										
United Kingdom	2		46	10	10	31																						
Netherlands	3		32	67																								
Finland	4		21	21	58																							
Denmark	5				32	59	6																					
Austria	6					6	90																					
Slovenia	7							85	11																			
Germany	8							11	83																			
Irland	9									14	13	43	6	13														
France	10									6	29	17	34	11														
Czech Republic	11									33	7	25	14	21														
Estonia	12									44		7	28	9														
Luxembourg	13										42			11		10	8	14	8									
Spain	14													8	26	25	34											
Greece	15															11	7	6					22	23			21	
Bulgaria	16													13	37	26	9											
Cyprus	17												8	13	16	12	5	28	6	9								
Slovakia	18																		36	49								
Belgium	19																21		23	11	29	13						
Rumania	20														6	9	9	8	6		31	13			10			
Italy	21																			21		26	33	14				
Lithuania	22																	33	15		32		10					
Poland	23																							37	26	34		
Portugal	24																					10	10		37	25	16	
Latvia	25																					28	8	14	21	28		
Hungary	26																										18	82
Malta	27																						12	11		12	43	18

Note: Frequencies are calculated across 1000 simulated scenarios combining: measurement error of the raw data, imputation for missing values, normalisation method, aggregation function at the category level, and exclusion of a category. For example, the Netherlands is ranked in the 2nd position in 32% of scenarios, but in the 3rd position in 67% of scenarios. Frequencies lower than 5% are not shown. The baseline ranking is the reference ranking produced by the *Observatoire de la Compétitivité* in the *2008 Bilan Compétitivité* report.

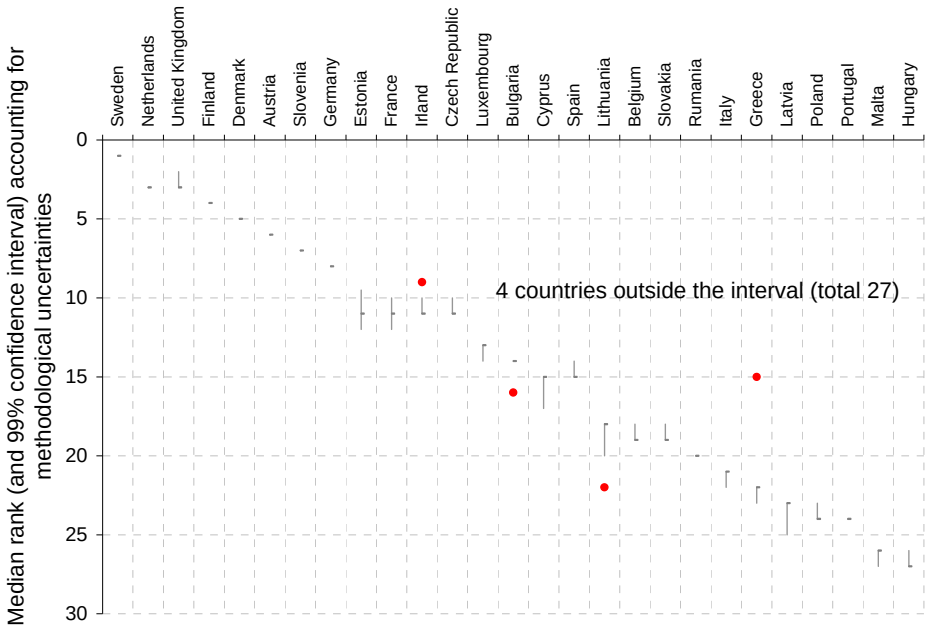
We acknowledge that in this analysis we have considered quite diverse scenarios and a more prudent approach would be to assess whether on average the Index rank is similar to the median rank across all the simulated scenarios, as we want to test whether the EU Competitiveness Index is, on average, summarising well the plurality of the scenarios. A further advantage to relying on the median performance is that any conclusions on comparative country performance would solely depend on the framework of the indicators and not on the methodological choices (e.g., imputation, normalisation or type of aggregation).

Figure 3 shows the median rank and its 99% confidence interval for each EU country and displays the name of countries whose baseline Index rank does not fall within this interval. Confidence intervals were estimated using bootstrap (1000 samples taken with replacement, see Efron, 1979). For 23 of the 27 countries, the baseline Competitiveness rank falls within this interval, which suggests that these countries were ranked in the correct place, on average. Four countries appear to be slightly misplaced − Greece,

Ireland, Lithuania and Bulgaria. Greece has been favored by seven positions, and Ireland by two positions due to the choices, needless to add non-intentionally, made in the construction of the Competitiveness Index. On the other hand, Lithuania and Bulgaria were placed in a lower position (four and two places, respectively) than our simulations would suggest. Any messages conveyed by the Index for those four countries should, therefore, be formulated with great caution and considered only as suggestive and contingent on the original methodological assumptions made in developing the Index.

A positive result of this analysis is that the narrow confidence interval for all EU countries suggests that there is no particularly volatile section in the graph and that almost all EU countries see little change in their position, on average (always less than two positions). These narrow confidence intervals suggest that robust conclusions (on average) on the relative performance of EU countries can be drawn.

Figure 3. Simulated median and its 99% confidence interval for the Index ranks



Note: The – indicates a country's median rank calculated over the set of plausible scenarios (roughly 1000) generated in our uncertainty analysis. Baseline ranks that fall outside the confidence interval for the median rank are marked in red (Ireland, Bulgaria, Lithuania, Greece).

This analysis has shown that if one accepts the current framework for measuring EU competitiveness at national level, only four countries' performance needs to be treated with caution because it depends strongly on the methodological choices. The remaining 23 countries are ranked correctly (eventually one position shift compared to the baseline ranking).

5.3 Sensitivity analysis results

Complementary to the uncertainty analysis, a sensitivity analysis makes it possible to assess the impact of a scenario on the Index ranking. To this end, we calculate for each country the absolute rank shift between the baseline rank and the rank provided by a given scenario and then summarise these shifts over all 27 countries by using the 50th percentile, the 90th percentile and the Spearman rank correlation coefficient, which serve as our sensitivity measures. Table 15 provides the results for all those scenarios that employ the full framework (82 indicators -10 categories) without the assumption of the measurement error. First, we discuss the impact of the assumptions taken singularly, and second, the combined impact of the assumptions on the final ranking.

What is the impact of hot-deck imputation as opposed to "no imputation"?

The simulations showed that the impact of using hot-deck imputation as opposed to "no imputation" − without considering interaction effects with other assumptions− is moderate: 1 out of 2 countries shifts less than 1 position with respect to the baseline ranking, whilst 9 out of 10 countries shift 3 positions or less. The most affected countries by this assumption are: Cyprus (up by five positions), Greece (down by eight positions), Lithuania (up by four positions). The Spearman correlation between the original ranking and this scenario is 0.952.

What is the impact of standardization of the raw data as opposed to min-max scaling?

The impact of standardisation is even more moderate than the assumption on imputation: 1 out of 2 countries shifts less than 1 position with respect to the original ranking, whilst 9 out of 10 countries shift 2 positions or less. The most affected countries by this assumption are: Bulgaria (up by three positions), Luxembourg (down by four positions), and Romania (up by six positions). The Spearman correlation between the original ranking and this scenario is 0.974.

What if the aggregation function is geometric instead of arithmetic?

When a partially compensatory aggregation is performed at the category level using the geometric mean function instead of the arithmetic mean, the impact on the original ranking is very moderate. The majority of the countries shift zero or one position, while the most affected countries −Denmark, Estonia, Italy − move four or three positions only. The Spearman correlation between the original ranking and this scenario is 0.98.

The impact of the Borda-adjusted aggregation instead is more pronounced; under this assumption half of the countries shift less than one position but the most affected countries shift six or seven positions. The most affected countries are Greece, Ireland, Slovakia and Romania. Overall, the Spearman correlation coefficient between the original ranking and this scenario is 0.933.

Interestingly, although both the geometric aggregation and the Borda approach aim to mitigate for compensability issues, the countries that are most affected by these assumptions are totally different. This result shows that there is no single way to deal with compensability issues and that different aggregation approaches can affect different countries.

The impact of the combined assumptions is still acceptable for the majority of the countries. The most influential assumption is the use of the borda-adjusted aggregation method combined with the hot-deck imputation. The impact of this assumption is equivalent to half of the countries (i.e. 13 countries) shifting less than 1 position and three countries shifting more than seven positions − Greece, Ireland, Malta and Slovakia. However, even in this case the Spearman correlation between the original ranking and this scenario is 0.895.

Table 15. Sensitivity analysis: impact of the assumptions on the Index ranking

Normalisation	Imputation	Aggregation	50th percentile (of absolute shifts in rank)	90th percentile (of absolute shifts in rank)	Spearman rank corr.
minmax	yes	Borda-adj.	1	7	0.895
minmax	no	Borda-adj.	1	6	0.933
standardisation	yes	Borda-adj.	1	5	0.905
standardisation	no	Borda-adj.	1	5	0.923
standardisation	yes	Arithmetic	2	4	0.924
minmax	yes	Geometric	1	4	0.938
standardisation	yes	Geometric	1	4	0.948
standardisation	yes	Arithmetic	1	4	0.953
minmax	yes	Arithmetic	1	3	0.952
standardisation	no	Arithmetic	1	2	0.974
minmax	no	Geometric	1	2	0.980
standardisation	no	Geometric	1	2	0.981

Note: The original ranking is employs min-max normalisation for the raw data, no imputation and arithmetic aggregation.

What if measurement error is incorporated?

A normally distributed random error term was added to the raw data with a mean zero and a standard deviation ranging between 0.2 to 2 times the observed standard deviation for

each indicator. Overall, the introduction of measurement error in the raw data assuming up to 0.5 times the observed standard deviation has a negligible impact on all countries, that is ± two positions change in the worst cases (Table 16). For greater measurement errors (0.75 times the observed standard deviation or more) the impact becomes more pronounced, in particular for Germany, Austria, Belgium, Bulgaria, Cyprus, Estonia, France, Hungary, Malta, Poland and Slovenia. It is interesting to note that the maximum shifts in country ranks are not proportional to the degree of the measurement error. Take for example the cases of Bulgaria and Cyprus, both declining by six positions when a measurement error equal to 1.5×std is added, but shifting by only one position when a greater measurement error is added (2×std).

Table 16. Sensitivity analysis: impact of the measurement error on the Index ranking

Country		Shifts in rank compared to the baseline scenario						
	Baseline rank	**0.2×std**	**0.5×std**	**0.75×std**	**1×std**	**1.25×std**	**1.5×std**	**2×std**
Germany	8	1	1	-1	-1	1	-2	-5
Austria	6	0	0	0	2	-6	-2	-2
Belgium	19	0	-2	2	1	0	-2	6
Bulgaria	16	-1	0	-3	-3	-1	-6	1
Cyprus	17	1	2	-1	2	-2	-6	-1
Denmark	5	0	0	-1	1	2	1	-3
Spain	14	-1	-1	1	1	-1	4	1
Estonia	12	0	1	2	0	-3	-6	-6
Finland	4	0	-1	0	-2	-2	-1	-3
France	10	-1	-2	0	-1	-3	-7	-1
Greece	15	-1	-1	1	-1	-3	-1	-4
Hungary	26	0	1	0	0	4	5	9
Irland	9	0	0	-3	-5	0	0	2
Italy	21	0	0	-1	-1	2	2	-1
Latvia	25	0	0	0	1	2	4	2
Lithuania	22	0	1	5	0	2	2	3
Luxembourg	13	-1	-2	-4	-3	-4	1	-5
Malta	27	0	0	1	0	5	7	5
Netherlands	3	0	1	0	-1	-2	-2	-1
Poland	23	0	1	2	4	2	6	7
Portugal	24	0	1	0	2	0	1	2
Slovakia	18	1	0	3	-1	3	2	-3
Czech Rep.	11	1	1	-5	-1	1	-1	-5
Romania	20	1	0	0	2	5	3	2
UK	2	0	-1	-1	-2	-1	-3	-3
Slovenia	7	-1	0	-1	1	-1	-4	-7
Sweden	1	0	0	0	-1	0	-1	-1

Note: Positive (/negative) numbers represent improvement (/decline) with respect to the baseline rank

What if a category is excluded?

Table 17 compares the country ranks for the 27 EU countries obtained using the baseline scenario (all ten categories included) versus the ranks obtained using only nine categories. Overall, eliminating any of the categories has a moderate impact on most of the countries (zero or less than two positions change). However, some countries are noticeably affected when a specific category is eliminated. For example, Estonia gains six positions in the overall classification of the EU27 (moves from 12th to 6th) when the Social Cohesion category is excluded (Estonia scores last in Social Cohesion), but loses eight

positions when the Employment category or Institutional & Regulatory Framework category is excluded. Another notable example is Lithuania: whilst it is not affected strongly by eliminating any of the categories, it can improve its rank by 10 positions – move from 22nd to 12th thus well before Belgium and Luxembourg – if the Social Cohesion category is eliminated.

Table 17. Impact of excluding a category on the final Index ranking

Country		***Excluded category – change compared to the baseline ranking***									
	Baseline rank	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
Germany	8	1	-1	-1	0	1	0	0	-2	-1	0
Austria	6	0	1	0	0	0	0	0	0	-1	0
Belgium	19	4	3	-3	-1	6	4	-2	-3	-6	1
Bulgaria	16	-5	-2	3	-2	0	-1	-1	0	-3	0
Cyprus	17	1	-5	-2	6	-5	-1	-2	2	0	6
Denmark	5	0	-2	1	-1	0	3	0	1	0	0
Spain	14	1	-1	-1	-1	0	0	-1	-1	-1	-3
Estonia	12	0	-8	2	-4	-8	1	-2	-1	6	-1
Finland	4	0	1	1	0	0	0	0	-1	0	0
France	10	0	2	-4	-3	0	0	0	-2	-3	0
Greece	15	1	2	-1	-2	4	-6	2	3	1	0
Hungary	26	0	2	0	0	0	2	-1	0	0	-1
Ireland	9	0	-1	1	0	-3	-4	0	1	1	2
Italy	21	2	3	-2	-1	3	2	1	-1	0	-3
Latvia	25	1	-2	3	-2	0	3	-1	0	5	-1
Lithuania	22	0	-1	-2	1	-1	2	-2	3	10	3
Luxembourg	13	-6	1	2	-1	-4	1	2	-5	-5	1
Malta	27	0	1	0	2	0	2	4	0	0	2
Netherlands	3	0	-1	1	1	1	0	0	1	0	0
Poland	23	-2	2	5	-1	2	0	-2	0	0	1
Portugal	24	1	-1	-1	1	-1	-2	8	0	0	1
Slovakia	18	1	4	-2	5	3	2	-4	-2	-4	-2
Czech Republic	11	0	-1	-1	1	1	2	-1	2	0	-3
Romania	20	-1	1	3	1	1	-7	2	2	3	-1
United Kingdom	2	0	0	-3	-1	-2	-3	0	-1	1	0
Slovenia	7	-1	1	0	0	-1	0	0	0	-3	-2
Sweden	1	0	0	0	0	0	0	0	0	-1	-1

Note: Positive (/negative) numbers represent improvement (/decline) with respect to the baseline rank

The analysis in this Chapter has shown for which countries the rank is not sensitive to the methodological choices and for which countries it is sensitive and under which assumptions. But, this analysis has taken the conceptual framework for granted. We would argue, though, that a framework mostly reflects the normative assumptions of its developers, and that as such it can be more appropriately the subject of the critique of experts in the field. However, Chapters 3 and 4 have already offered some "statistically-driven" recommendations for the revision of the framework that need to be coupled with expert opinion on competitiveness issues. The methodological assumptions instead have been tested with the usual tools of applied statistics – by uncertainty and sensitivity analysis.

It is recommended that the uncertainty and sensitivity analysis are repeated once the framework has been revised.

6. Policy implications

The Competitiveness Index by the *Observatoire de la Compétitivité* and the ten categories of competitiveness by the Fontagné report could provide useful material for the analysis of the phenomenon in the European Union. A high Index (or category) score means that a particular country has better competitiveness conditions than a country with much lower scores. While an EU country will score higher than some and lower than others, the purpose of the Competitiveness Index is not to identify winners and losers. Instead, the Index and its ten categories could foster discussions about what factors contribute to good competitiveness performance at national level and also provide insight into the nature of relevant policy challenges at the EU level.

6.1 Challenges for competitiveness in the EU

Figure 4 shows that at EU level, the best overall performance is found in the categories: Market Operations (D), Education & Training (G), and Social Cohesion (I), in which half of the countries score more than 65 points. However, in two of the categories, national performance is particularly worrying. In the Entrepreneurship (F) and Knowledge Economy (H), half of the countries do not score more than 40 points. These two categories pose the highest challenges for competitiveness at the EU scale.

A comment that was discussed earlier in Chapter 4 was the fact that many of the categories have random associations between them and consequently the interpretation of the final Index results may be cumbersome. In fact, we observe that although an

overall classification has been provided for the 27 EU countries, the final competitiveness scores range between 42 and 65 points. Hence, all countries have moderate performance in terms of competitiveness. Further recommendations that stem from this observation are:

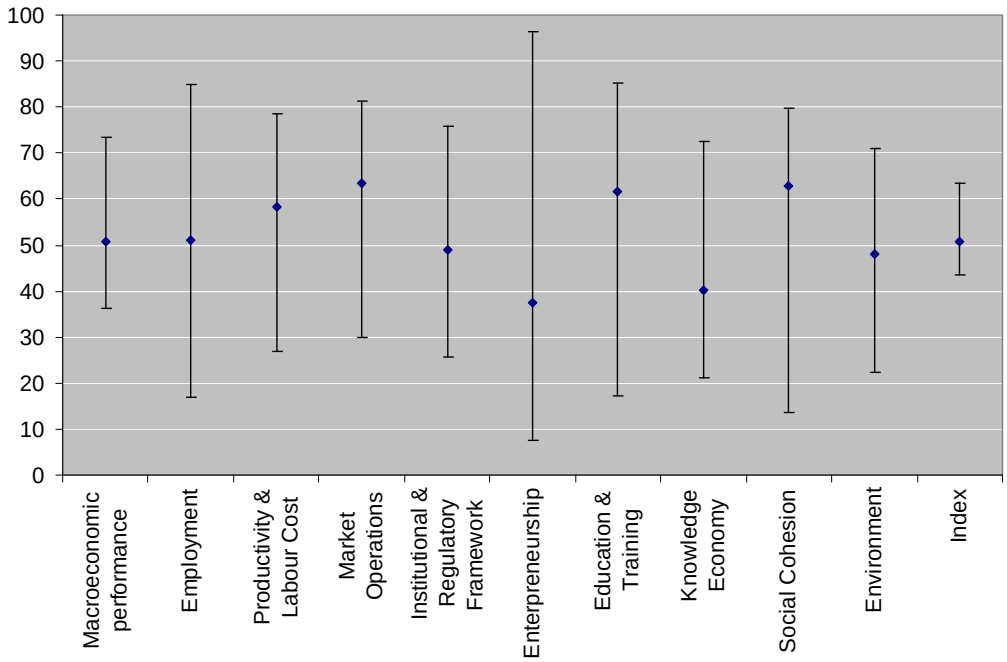
a. the ten categories should not be further aggregated, as such, into a single index, but presented as a thematic indicator of ten composites (already done in the various reports of the *Bilan Compétitivité)*,

b. a revision is needed to arrive at a more coherent framework,

c. a min-max scaling could be applied also at the ten categories (in addition to the normalisation of the indicators), in order to balance the impact of the categories at the aggregation.

These three recommendations could either be considered individually or simultaneously.

Figure 4. Competitiveness in the EU countries: Index and category scores



Note: Blue dots represent the median score across the 27 EU countries within a category or the Index. Bars represent minimum and maximum scores.

6.2 Exceptional behaviour of some EU countries

The Competitiveness Index shows that there is no ideal EU country excelling in all ten categories, but rather that there is space for improvement in every country. Although the most competitive countries are (in alphabetical order) Denmark, Finland, the Netherlands, Sweden, and UK, and the least competitive are (in alphabetical order) Hungary, Latvia, Malta, Poland, and Portugal, the differences in those country scores are not so pronounced. In fact the top 5 countries score between 59 and 63 points, whilst the bottom 5 countries score between 43 and 47 points.

EU countries which perform well in the overall Index generally perform well in most of the ten categories. There are, however, a few exceptions (Table 18). The UK is ranked top 7 overall, but bottom 7 in Macroeconomic Performance and in the Knowledge Economy. Similar is the case for Denmark, Finland and Sweden: they are all among the top 7 overall but among the bottom 7 countries in the Entrepreneurship category.

On the other hand, there are seven countries which excel in one of the ten categories, but remain in the bottom 7 in the overall classification. These countries are: Latvia excelling in Market Operations, Malta in the Institutional & Regulatory Framework and in the Social Cohesion, Poland and Portugal in Entrepreneurship, Lithuania in Education &Training, and Hungary excelling in the Environment. No such peculiarities are observed for the Employment and Productivity & Labour Cost categories.

Table 18. Exceptional behavior of EU countries in Competitiveness aspects (top/bottom quartiles)

	Index	
Category	**Top 7**	**Bottom 7**
A. Macroeconomic performance		
Bottom 7	United Kingdom (2nd , 22nd)	
D. Market operations		
Top 7		Latvia (25th,4th)
E. Institutional & Regulatory Framework		
Top 7		Malta (27th, 5th)
F. Entrepreneurship		
Top 7		Poland (23rd, 3rd) Portugal (24th, 4th)
Bottom 7	Denmark (5th, 27th) Finland (4th, 24th) Sweden (1st, 26th)	
G. Education & Training		
Top 7		Lithuania (22nd, 5th)
H. Knowledge Economy		
Bottom 7	United Kingdom (2nd, 23rd)	
I. Social Cohesion		
Top 7		Malta (27th, 2nd)
J. Environment		
Top 7		Hungary (26th, 5th)

7. Conclusions

The 2008 Competitiveness Index, developed by the *Observatoire de la Compétitivité* distils key aspects of competitiveness in ten main categories along the lines of the Fontagné report: (1) Macroeconomic performance, (2) Employment, (3) Productivity & Labour Cost, (4) Market Operations, (5) Institutional and Regulatory Framework, (6) Entrepreneurship, (7) Education & Training, (8) Knowledge economy, (9) Social Cohesion, and finally (10) Environment. These categories include a total of 82 indicators.

The difference between the Scoreboard of Competitiveness of the Fontagné report and most of the other indices is that it has been tailor-made to the needs of the European Union, including also most of the Lisbon indicators. Furthermore, the Observatoire de la Compétitivité is very clear about the definition of competitiveness: "*Competitiveness is the capacity of a nation to durably improve the standard of living of its inhabitants and to procure for them high levels of employment and social cohesion while preserving the environment.*"

As always when combining statistical indicators to capture a complex dimension, the Competitiveness Index contains normative as well as analytic ingredients, in a mixture of that serves both analysis and advocacy addressed to the EU 27 Member States.

We subjected the 2008 Competitiveness Index to thorough validity testing. First we assessed whether the Scoreboard of Competitiveness from the Fontagné report is a proper conceptual framework to construct a final Index. Our results suggest that although the Scoreboard is a good basis for an Index, it needs to be revised to overcome few shortcomings. The recommendations offered in this respect are the following:

- In the Employment category (B), the indicators on total employment rate (B1) and total employment rate of persons aged 55-64y (B4) could be excluded from the framework, given that the equivalent rates for men and women are already included.

- In the Productivity and Labour costs category (C), the indicators on trends in total factor productivity (C1) and trends in apparent work productivity (C2) could be combined. Similarly, in the Institutional & Regulatory Framework category (E), the administration efficiency index (E6) could be combined with the observance of the law index (E7), and the degree of sophistication of online public services (E9) combined with the public services fully available online (E10). In the Knowledge Economy category (H) the number of USPTO patents (H7) and number of OEB patents (H8) could be combined. Finally, in the Social Cohesion category (I), three indicators could be combined: the gini coefficient (I1), at persistent risk of poverty rate (I3), and at-risk of poverty rate after social transfers (I2). In practical terms, combining two indicators is equivalent to assigning them 0.5 weight each when all other indicators in the category receive a weight of 1 each.

- The Entrepreneurship category is negatively associated to Education & Training, Knowledge Economy and Social Cohesion and randomly associated to all other categories. This result suggests that in the current framework, there is a trade-off between competitiveness and entrepreneurship and the more competitive countries are those with lower entrepreneurship scores. If this conclusion sounds unfounded, then the entrepreneurship category and the underlying indicators may need revision.

- In the Environment category, almost all underlying indicators have very low or even random associations to the category scores. Consequently, the environmental indicators have very little impact on the competitiveness scores, despite being part of

the conceptual framework. To mitigate this, a greater weight could be assigned to the category on Environment, so as to effectively have an equal weight to the other categories. In addition, some of the ingredients of the 2010 Environmental Performance Index by Yale and Columbia University could be considered. Finally, the existence of trade-off in some enviroenmental indicators appears as an odd outcome: the more energy intensity economies have lower values in greenhouse gas emissions and less waste generated.

- Twenty five indicators (listed in Table 9) are randomly associated with either the Index and/or with the Category they belong to. These indicators include real growth rate of GDP, total greenhouse gas emissions, energy intensity of the economy, total state aid, portion of public research financed by the private sector. The random association between the Index (and category) scores and these indicators should not be taken to mean that these indicators do not describe important aspects of competitiveness. However, these random associations imply that even if some EU countries improve their relative performance in any of those indicators, this improvement will not lead to an overall improvement in the relevant category score or in their final Index score. An eventual revision of the framework could focus on reducing the 82 indicators into a smaller number of indicators that all play an important role in the classification of the EU countries. At the same time, if all Lisbon indicators are meant to be important to determining the competitiveness level of the EU countries, then some modifications to the conceptual framework are needed to include these impacts too. It is evident, that simply placing a Lisbon indicator in the framework does not provide any guarantee that the indicator will have a significant impact on the results, as was the case for real growth rate of GDP, total greenhouse gas emissions, and energy intensity of the economy.

- Many of the categories have random associations between them and consequently the interpretation of the final Index may be cumbersome. In fact, despite the classification from 1st to the 27th position, the competitiveness scores for the EU countries range between 42 and 65 points. Hence, all countries have moderate performance in terms of competitiveness. Recommendations that stem from this observation are: (a) the ten categories should not be further aggregated into a single index, but presented as a thematic indicator of ten composites (already done in the Bilan Compétitivité reports), (b) a revision is needed to arrive at a more coherent framework, (c) a min-max scaling could be applied also at the ten categories level to balance their impact.

- Assigning equal weights to the ten categories has not guaranteed an equal impact on the results. The analysis of the effective weights suggests that the most influential categories are Employment, Knowledge Economy, and Education & Training, followed by Social Cohesion. The least influential Categories are Productivity and Labour Costs, and the Environment. Thus, a greater nominal weight could be assigned to the latter two categories to guarantee an equal effective weight with respect to the other categories. Alternatively, a better match between the nominal and the effective weights would be obtained, at least for some of the categories, by re-scaling the category scores with the min-max approach prior to finally aggregating them into a final Index.

Some further suggestions on data quality issues relate to:

- Cross-checking the reported results, as four country names seem to have been switched: the results for Romania have erroneously been assigned to Slovakia, and vice versa, and the results for the United Kingdom have erroneously been assigned to Czech Republic, and vice versa.

- Although overall data coverage is excellent (92%), there are few countries with important data gaps (roughly 50% missing) within certain categories. This is the case for Malta, Bulgaria, Cyprus, Romania, Lithuania, Lithuania, Estonia, Slovenia, Greece, Poland, Ireland and Germany for categories such as Market Operations, Entrepreneurship and Knowledge Economy (see Table 4 for more details). A footnote on the country scores for those categories should be added. At the indicator level, the trends in total factor productivity (C1) and at persistent risk of poverty rate (I3) miss more than half of the country values. In the present case, given that the Index is made of 82 indicators, eliminating those two indicators would leave the results practically unaffected. In any case it is recommended that the two indicators are maintained in the conceptual framework but a note on poor data coverage is added.

- Seven indicators are flagged for further consideration as they exhibit relative high values for skewness and kurtosis (see Table 2): gross national income (A1), terms of trade (A9), FDI inflows/outflows (A12), market share of primary operator in the cellular market (D4), basket of domestic royalties for 2Mbits leased lines (D8), number of researchers (H5), and energy intensity of the economy (J6). The few

outlier values in those indicators could be treated by winsorization, that is by resetting outlier values to the second (or third best) value as shown in Table 5.

- The "no imputation" choice for treating missing data can heavily distort the correlation structure. It is suggested to use the hot-deck imputation method within each category instead.

Next, we conducted an uncertainty analysis to assess the impact on the Competitiveness ranking of simultaneous variations in the methodological assumptions related to the measurement error in the raw data, the imputation, the normalisation method, the aggregation function at the category level and the exclusion of a category from the framework. The effect proved to be non significant for 23 countries, but important for the remaining four countries − Ireland, Bulgaria, Lithuania and Greece. Any Index-driven narrative on those countries should be considered only as contingent on the original methodological assumptions made in developing the Index.

Overall, the 2008 Competitiveness Index gives a fair representation of the ensemble of models considered: the Spearman correlation between the final ranking and the simulated median ranking is 0.972, whilst with the most extreme scenario (that employs Borda-type aggregation and hot-deck imputation) is 0.895. These results suggest that the overall 2008 Competitiveness ranking provides a reliable picture of the situation at the national level in the EU and can be used to generate a discussion about what policies contribute to competitiveness, to study the association between competitiveness and other concepts, and to provide insight into the nature of competitiveness policy challenges at the EU scale.

Data-driven narratives on competitiveness issues in the European Union are also offered in order to draw attention to messages and debates that may stem from an index-based analysis of competitiveness. Important findings suggest that:

The Entrepreneurship and Knowledge Economy categories pose the highest challenges for competitiveness at the EU scale − half of the EU countries do not score more than 40 points (best possible score is 100 points).

The distances between the most and least competitive EU countries are small − the top 5 countries score between 59 and 63 points (Denmark, Finland, the Netherlands, Sweden, and UK, alphabetical order), whilst the bottom 5 countries score

between 43 and 47 points (Hungary, Latvia, Malta, Poland, and Portugal, alphabetical order).

There is space for improvement in all EU countries – e.g., the UK is ranked in the top 7 overall but bottom 7 in Macroeconomic Performance and Knowledge Economy. Similarly, Denmark, Finland and Sweden are top 7 overall but bottom 7 in Entrepreneurship. On the other hand, some countries excel in a single category, but remain in the bottom 7 in the overall classification (Latvia excels in Market Operations, Malta in the Institutional & Regulatory Framework and in the Social Cohesion, Poland and Portugal in Entrepreneurship, Lithuania in Education &Training, and Hungary excels in the Environment category).

From the point of view of implications, the assessment carried out on the 2008 Competitiveness Index does not represent merely a methodological or technical appendix. Composite measures are often attached to regulatory mechanisms whereby governments or organizations are rewarded or penalised according to the results of such measurements. The use and publication of composite measures can generate both positive and negative behavioural responses and if significant policy and practice decisions rest on the results, it is important to have a clear understanding of the potential risks involved in constructing a composite and arriving at a ranking or benchmarking.

The auditing conducted herein has shown the potential of the Competitiveness Index developed by the *Observatoire de la Compétitivité*, upon some refinements, in reliably identifying weaknesses and ultimately monitoring national performance in the EU countries.

Annex

Table A 1. Descriptive statistics for the 82 indicator underlying the Competitiveness framework

	Valid N	Mean	Median	Minimum	Maximum	Std.Dev.	Skewness	Kurtosis
A1	27	98.04	97.00	39.00	258.00	42.74	1.92	6.69
A2	27	0.01	0.01	-0.05	0.07	0.03	0.02	0.04
A3	27	0.01	0.01	-0.01	0.05	0.01	0.44	0.46
A4	27	0.06	0.06	0.03	0.11	0.02	0.47	0.87
A5	27	0.05	0.04	0.02	0.15	0.03	1.82	2.69
A6	27	-0.02	-0.03	-0.07	0.04	0.03	0.40	-0.65
A7	27	0.46	0.43	0.05	1.06	0.27	0.50	-0.41
A8	27	0.03	0.03	0.01	0.06	0.01	0.19	-1.18
A9	27	102.22	102.00	88.00	132.90	8.15	2.05	7.29
A10	19	109.23	108.30	105.40	119.00	3.24	1.69	3.48
A11	27	0.82	0.83	0.70	0.88	0.04	-1.22	2.77
A12	27	0.20	0.05	0.01	3.50	0.66	5.13	26.50
B1	27	0.66	0.67	0.55	0.78	0.06	0.05	-0.53
B2	27	0.73	0.73	0.63	0.83	0.05	0.09	-0.10
B3	27	0.60	0.61	0.37	0.74	0.08	-0.57	0.45
B4	27	0.46	0.46	0.29	0.70	0.11	0.13	-0.89
B5	27	0.56	0.59	0.39	0.73	0.10	-0.32	-0.99
B6	27	0.38	0.36	0.12	0.67	0.13	0.33	-0.46
B7	27	0.15	0.15	0.05	0.25	0.05	-0.03	-0.79
B8	27	0.02	0.02	0.01	0.07	0.01	1.28	2.94
B9	27	0.14	0.12	0.02	0.47	0.10	1.45	2.97
C1	15	-0.01	-0.01	-0.06	0.01	0.02	-1.60	3.14
C2	27	0.00	0.00	-0.06	0.06	0.03	-0.37	1.32
C3	27	0.63	0.61	0.17	0.97	0.24	-0.21	-1.24
C4	27	0.02	0.02	-0.02	0.10	0.03	1.20	1.67
C5	27	0.53	0.54	0.30	0.73	0.11	-0.20	-0.20
D2	27	0.09	0.09	0.05	0.14	0.02	0.26	-0.06
D3	24	8.61	8.73	5.72	12.49	1.71	0.38	0.18
D4	25	0.46	0.45	0.26	0.90	0.13	1.99	5.83
D5	19	1380.22	1213.93	731.24	2613.12	576.35	1.15	0.42
D6	19	652.27	655.26	327.09	1191.50	236.74	0.43	-0.30
D7	19	42.89	43.92	29.22	78.86	11.98	1.40	3.35
D8	19	580773.91	26949.77	5945.10	6957370.00	1696318.31	3.46	12.30
D9	27	0.04	0.04	0.01	0.12	0.03	1.54	3.07
D10	27	0.01	0.01	0.00	0.01	0.00	0.82	-0.43
E1	27	0.23	0.25	0.10	0.35	0.07	-0.25	-0.88
E2	25	0.41	0.41	0.19	0.60	0.10	-0.32	-0.37
E3	27	0.19	0.19	0.15	0.25	0.02	0.46	1.15
E4	19	0.43	0.43	0.23	0.56	0.08	-0.56	1.05
E5	19	0.32	0.36	0.05	0.44	0.10	-1.23	1.19
E6	27	1.15	1.15	-0.14	2.19	0.61	-0.27	-0.71
E7	27	1.14	1.05	-0.12	1.92	0.61	-0.37	-0.81
E8	27	1.29	1.25	0.53	1.91	0.38	-0.08	-0.86

E9	27	0.77	0.80	0.53	0.99	0.13	-0.26	-0.89
E10	27	0.60	0.63	0.15	1.00	0.23	-0.03	-0.79
F1	25	0.43	0.41	0.30	0.58	0.09	0.30	-1.39
F2	26	0.16	0.14	0.05	0.35	0.08	1.02	0.86
F3	21	0.01	0.01	-0.07	0.09	0.03	-0.16	1.85
F4	21	0.19	0.17	0.13	0.28	0.04	0.78	-0.11
G1	27	5736.47	6368.50	1450.10	14041.30	2562.91	0.95	2.97
G2	27	0.73	0.78	0.28	0.91	0.17	-1.57	2.38
G4	27	0.39	0.40	0.22	0.50	0.08	-0.43	-0.38
G5	27	0.10	0.08	0.01	0.32	0.08	1.56	2.02
G6	27	0.15	0.13	0.04	0.37	0.08	1.62	2.54
H1	27	0.01	0.01	0.00	0.04	0.01	0.92	-0.12
H2	27	0.40	0.41	0.03	0.67	0.16	-0.25	-0.12
H3	19	0.08	0.07	0.01	0.16	0.05	0.26	-1.08
H4	19	0.06	0.05	0.01	0.19	0.05	1.07	1.54
H5	23	6.26	5.70	1.43	15.60	2.95	1.40	3.61
H6	27	414.34	386.44	41.00	1108.75	300.84	0.70	-0.35
H7	27	32.86	6.65	0.44	155.10	42.25	1.43	1.52
H8	27	81.23	32.10	1.35	275.05	90.17	0.89	-0.68
H9	27	0.85	0.87	0.60	0.97	0.10	-0.94	0.22
H10	19	0.02	0.02	0.01	0.04	0.01	0.57	-0.12
H11	27	0.57	0.58	0.25	0.86	0.17	-0.01	-0.59
H12	19	155.39	153.09	103.67	225.46	26.85	0.32	2.09
H13	27	0.80	0.84	0.45	0.95	0.11	-1.32	2.52
H14	19	23.54	14.02	2.62	58.48	20.22	0.47	-1.37
H15	27	0.06	0.06	0.01	0.11	0.03	0.16	-0.45
I1	27	0.29	0.28	0.23	0.37	0.04	0.24	-1.23
I2	27	0.15	0.15	0.10	0.21	0.04	0.08	-1.45
I3	14	0.10	0.09	0.06	0.15	0.03	0.43	-1.15
I4	27	77.82	79.52	70.92	81.09	3.32	-0.93	-0.65
I5	27	0.15	0.14	0.03	0.25	0.06	0.05	-0.83
I6	27	82.19	83.00	52.00	126.00	16.42	0.34	0.78
J1	27	635.17	505.45	150.26	1942.88	400.48	1.76	3.46
J2	27	116.55	83.82	14.67	415.39	96.41	1.55	2.49
J3	27	95.07	94.20	46.60	185.30	34.46	0.73	0.40
J4	27	0.16	0.09	0.00	0.60	0.15	1.43	1.77
J5	27	524.00	518.00	294.00	801.00	137.51	0.32	-0.32
J6	27	294.65	198.18	103.13	1016.29	215.41	1.82	3.61
J7	25	92.42	91.60	66.90	137.40	15.39	0.94	2.13

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