Workpackage 3

Quality of Knowledge Economy Indicators

Deliverable 3.3

2008

List of contributors:

Nicole Thees, Ralf Münnich, Jan-Philipp Kolb, Stefan Zins, University of Trier

Main responsibility:

Nicole Thees, Ralf Münnich, Jan-Philipp Kolb, Stefan Zins, University of Trier

CIS8–CT–2004–502529 KEI

The project is supported by European Commission by funding from the Sixth Framework Programme for Research.

http://europa.eu.int/comm/research/index_en.cfm

http://europa.eu.int/comm/research/fp6/ssp/kei_en.htm

http://www.cordis.lu/citizens/kick_off3.htm

http://kei.publicstatistics.net/

Preface

Measuring the Knowledge Economy leads immediately to a whole bunch of information which is then put into indicators that describe certain aspects of the Knowledge Economy. The available information within the KEI project leads to the need of compressing information to get a better overview. Besides many important aspects as it regards content, one may consider the quality of single indicators in order to discard possibly misleading information.

The present deliverable is the follow up of deliverable 3.1 where general quality concepts have been discussed. Its aim is to present a clear definition and concept of quality measurement for indicators in general and composite indicators in particular. Moreover, the results of the quality measurement for the KEI indicators and its problems are presented.

The authors would like to thank Mr. Håkan Linden, Eurostat, and Mr. Mikael Åkerblom, Statistics Finland, for their helpful comments. Further we are thankful to many inspiring discussion within the KEI team.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

In order to analyze complex phenomena and to give recommendations for shaping their future development, a quantification of facts as information is useful and even important. For developing applicable indicators it is inalienable to define a list of desiderata. Especially for a multidimensional phenomenon like the knowledge economy a multitude of indicators and also composite indicators are necessary for measuring the quantity of interest. This is especially relevant for the measurement of target achievements in connection with the Lisbon and Barcelona goals.

The Lisbon goals (see European Council, 2000) do comprehend various issues of the Knowledge Economy and Innovation Society as general targets. Indicators do play an important role to measure the degree of target achievement but also to give a frame for the understanding of the knowledge economy. Yet, key issues of European policy are to control for development and to give a basis for benchmarking procedures. Several indicators are designated to grasp the phenomena of the Knowledge Economy. The set of indicators within the KEI project comprehends altogether 144 indicators (a detailed overview can be seen in Figure A.3). These indicators do differ, not only in content and scale units but also in survey design and entry date.

The performance assessment of the participating countries from the European Union is a matter of primary concern. Indicators have to be comparable to afford the benchmarking process within the European Union. Moreover it is crucial to pursuit the development of Knowledge Performance, therefore changes over time have to be examined.

The chosen indicators for the measurement of this assessment have to be comparable in a supra-regional context. Composite indicators are a powerful tool to measure kinds of multidimensional phenomena as well as to structure macroeconomic data. These kind of indicators are increasingly applied in policy analysis and public communication.

Composite indicators offer the opportunity to reduce the complexity of multidimensional phenomena and provide simple comparisons of countries in political relevant areas like environment, economy, society or technological development. One important reason for the use of composite indicators is that finding trends in many separate indicators is often more difficult than to identify these trends with one detached indicator. Accordingly to that fact composite indicators can be easier in their interpretation. They are therefore commonly used in benchmarking country performance. Whereas, it has to be considered that in the case of deficient construction, composite indicators can send ambiguous policy messages, which can be the origin of misinterpretation or too simplistic conclusions. (Nardo et al. 2005, p.8.). Moreover it is obvious that a composite indicator is just as good as the component parts are.

Due to the political and public relevance to reduce potential economic costs of misleading political decisions, the necessity for a well founded construction of these composites with well chosen indicators and underlying high quality data is obvious. This implies an enlargement of the established quality concept of single accuracy measurement in the sense of exactness or reliability. But self-evident also exigencies concerning coverage, accessibility or coherence have to be fulfilled. These quality dimensions are extended by requirements like comparability, reduction of user burden, and budget constraints.

The use of composite indicators implies a variety of data sources, e.g. survey samples or administrative data. Hence a quality analysis might offer the additional opportunity to give decision criterion concerning the indicator selection. Information on indicator quality can help to omit the choice of indicators with bad performance concerning the quality dimensions.

The deliverable 3.1 presents the different data quality frameworks, measurement concepts and publication methods of quality information. The aim of the following deliverable is to focus on the definition of indicators in general to ascertain good quality indicators as extension of data quality concepts.

As composite indicators are the aggregated result of single indicators, the need to define indicators as well as composite indicators under a quality perspective is apparent. In the following chapter 2 the theoretical concept of indicators will be discussed. Afterwards the next chapter will deal with the real circumstances of quality dimensions to be adopted in the Knowledge Economy coherence. In chapter 4 an application of the quality dimensions is exceeded before the results are outlined in the conclusion.

Chapter 2

Indicators in the Knowledge Economy and their Appraisement

To make useful comments on often subjective observations it is necessary to quantify these observations. In this coherence indicators are an useful tool to get quantitative information. But without quality control the deployed indicators are without use. The risk for the occurrence of misleading results would be to big. The indicators would not reflect the reality then. But quality concepts on this issue do comprehend a wide range of necessities which should be fulfilled. To describe the requirements of researchers on the field of Knowledge Economy and to develop and improve indicators on that research area, a general clarification of indicators is important. This clarification is one of the issues of this chapter.

2.1 Deployment of Appropriate Indicators

Unfortunately there is a lack of generally accepted and all-embracing definitions on European level. Due to the fact that the understanding on Knowledge Economy as well as data sources and sampling schemes do differ between countries. Another reason is the fact that the research field of the Knowledge Economy was defined quite recently. Therefore it is not yet common sense which phenomena are important for this field.

The fact that also non member states of the European Union are included in the research topic of the KEI project makes the declaration of definitions even more complicated. The inclusion of non member states is exceeded, basically to have a basis for comparison between the performance of member states with the performance of non member states. But for the non member states it is sometimes complicated to adopt European definitions. And it is even more complicated to find definitions if there are not yet general accepted definitions on the EU level.

The definition of indicators does differ not only between different countries but also between different research disciplines. In Business Administration for example a Key Performance Indicator is used to measure the degree of target achievement. A different example for the use of indicators is the open method of coordination. Within this process the requirement to appoint indicators was emphasized by the European Council. These indicators are designed in order to improve the monitoring procedure (Régent, 2002, p.5). This example shows the eminent importance of indicators in the context of policy interception in the European Union.

In the coherence of the KEI project indicators like *ICT expenditure*, *Number of patent applications*, or *percentage of individuals using the Internet for specific purposes* are used (The full set is to be found in Figure A.3). Where *ICT expenditure* for example is used as an indicator to measure current and future productivity improvements (Eurostat, 2008).

Indicators are accordingly used to operationalize developments. As already mentioned for classification and structuring of these indicators a indicator definition is crucial. As there are many regarding content different indicators, it is articulative that there are also several sources for indicator definitions. For example the definition of EUROSTAT is a crucial one in the introduced coherence but there are also numerous definitions in encyclopedias. One interesting approach to define indicators, is to assign the indicator against other related concepts like that of the indices.

In general an indicator is a measurable circumstance which has explanatory power concerning the topic of interest. It often results of secondary information strongly related to the investigated fact. Sometimes an indicator is also used as a term for indication. This would be thus a case of derived measurement (cf. v.d. Lippe 1990, p.29) . In this case the distance to a predetermined target value can be measured with an indicator. General definitions, as those of dictionaries resume, that indicators are either a device that point out or give information about a phenomenon, such as pressure, temperature, the departure times of trains, etc. or numbers, such as statistics or ratios derived from a series of observations (de Vries and Willern 2001, pp.314).

de Vries and Willern (2001) p.319 concludes, that an indicator might be:

> „. . . a statistic, or set of statistics, or other evidence, suited to assess a situation or a development, possibly against certain agreed goals.“

But he also states that this kind of definition might not be satisfying. Because it does not imply that an indicator can be a single number or another simple factual piece of information, but that it is a set of statistics or other evidence. Therefore he proposes additionally the definition that an indicator is a single number, a ratio or an other observed fact that serves to assess a situation or a development (de Vries and Willern 2001, p.319).

In contrast there are also different understandings on index numbers. On the one hand they are defined as composition of different indicators and on the other hand they are sometimes defined as simple measure. For example a statistical category of numbers which depict chronological developments of a amount of congeneric matters. These index numbers are the weighted mean of measured values thus a global characterization of a multitude of developments. Indices are indicating first of all a change in magnitude, or a relative change. At the outset changes in quantity such as wage or a price are measured, and compared with the level of that accordant value or quantity at an other point in time. Increase or decrease in index numbers between different moments can be depicted if the index is set at 100 as a base level. Then aberrations from this level can be stated as percentage change. With an index it is possible to disclose relative changes as a function in time. The price indices are examples for the second category whereas Human Development Index and Human Poverty Index are famous examples for the first category of indices.

The main difference between indicators and indices is thus the difference between indirect and direct measurement. Where the concept of indicators can be developed, so that this difference gets more apparent. If indicators are derived from more than one observation, the question of weighting the different parts has to be discussed. Especially CHERCHYE et al. 2007 refers to the controversy about the credibility of composite indicators.

The definition of an indicator can be specified with the empiricism theory. According to this, an indicator or a variable is defined as the empirical observed fact for a theoretical non-observable aspect using a pre-defined measurement specification. The aim is, to reduce the gap between theoretical and empirical measurable aspects. This is one of the main tasks of the economic and social statistical methodology. The German language provides a special technical term for this kind of gap reduction, the so called *Adäquation*. The English term *adequacy* does not have this special implication.

An example might underline the idea. One aspect to be measured in the KEI project is the *production and diffusion of ICT*. This issue can not be measured directly, therefore observable facts have to be found which do reflect the production and diffusion of these technologies. Empirically measurable are for example business receiving orders over the internet. Adequacy would be, to reduce the gap between the theoretical implication of production and diffusion of ICT and the empirical measured aspect of business receiving orders over the internet (MENGES 1972, p.40).

The ability of an indicator is, to point out the direction of change across different units and through time. This is done to recognize trends. Furthermore the target is to evaluate intervals and to identify particular issues consequential. Indicators can therefore be helpful in benchmarking or monitoring performance and in setting policy priorities (NARDO et al. 2005, p.8).

In this context the presentation of existing indicators seems to be easy. But the evaluation process until their dissemination is complex and requires a very good theoretical basis and this process should be transparent. It should be always clear what the background for an indicator selection or creation was. Sometimes practical reasons are more important than the theoretical foundation, sometimes it is the other way around.

Often the indicators selection is partially based on political consensus. Then normative criteria can play an important role, like they do for the following issues:

- about what is relevant to well-being,
- about what living conditions are favourable or unfavourable
- and which directions society should be moving towards.

But not only a Consensus between different concerned parties is important. Here a trade off between this political requests and more practical issues about the technical measurability, the reliability and the adequateness has to be realized.

Especially the construction of social indications is important in the present case. Here the selection of indicators often depends on valuation. It is not always evident that changes in society highlighted through the use of indicators are the consequential result of policies. The social *climate* is complex and subject to a variety of influences of which government action is only one. Therefore it should not be assumed that indicators are directly measuring the outcomes of policy or that policy can easily divert indicators from undesirable directions. Special attention should be made on the use of social indicators to extrapolate trends into the future (cf. Davey, 1998).

This shows that variety of aspects which have to be considered. Due to analytical reasons and to draw a more detailed picture of the interesting aspects, a sub-grouping or classification of the indicators, thematically or geographically is often meaningful.

Davey (1998) proposes the following possibilities to categorise indicators. She distinguishes between *external* - *objective* or *internal* - *subjective, perceptual* indicators. The first category consists of so called *hard* indicators, like the level of income or the number of patent applications. *Hard* means that there is not much room for interpretation. Often these kind of indicators are easily available through official surveys such as Censuses, the Labour Force Survey, or data from the health and education systems. The characteristics of these indicators suggest that they might be of good quality. But it is possible that there are problems occurring if they are used as a basis of comparison. Sometimes the indicators are not comparable due to the fact that two values in time or for different geographical units result from a situation with complete different basic conditions. As an example a price indicator might be connoted as an *hard* indicator, but if two indicators are compared in time it is quite hard to control for changes in quality.

The second category embraces the so called *soft* indicators as the basis of these indicators is not so clear defined. One good example here is the satisfaction with services or with the own job. Here it is possible that two persons with exactly the same circumstances do make differing statements concerning their working conditions. These type of indicators do require special surveys and an initial quality assessment might be vague (Davey 1998).

Another differentiation is the following de Vries and Willern 2001, p.320):

> A distinction that is not mentioned above, but that is nevertheless important is that between indicators designed to develop, analyse or monitor policies (*policy indicators*) and indicators that are mainly serving advocacy purposes *advocacy indicators*), such as the Human Development Index. *Advocacy indicators* probably not necessarily need to meet the same standards of scientific rigour as *policy indicators*.

Other classifications refer to quantitative or qualitative, direct or indirect, input, process, performance or outcome, driving force, state or response. If different indictors compose one new indicator maybe the most important classification has to be mentioned, that is the differentiation between simple or composite indicators. The principe of the composite indicators will be deployed in the following.

2.2 Deployment of Appropriate Composite Indicators

The construction of composite indicators as a function of a set of indicators is a wide used practice to structure relevant data (MUNDA and NARDO 2005, p.3). Composite Indicators are then synthetic indices. Individual indicators are compiled into a single indicator on the basis of an underlying model. These kinds of indicators are for example used to rank the performance of countries on different areas (FREUDENBERG 2003, p.3). It is possible to concentrate an huge amount of information to an easily understood format, that is the advantage of composite indicators. Moreover they are characterized by their ad hoc attribute. That means that they are often constructed to match on a special interest. Ideally they are used to measure multi-dimensional concepts which cannot be captured by a single indicator alone. Examples for such multidimensional concepts are competitiveness, industrialization, sustainability, single market integration, knowledge-based society, etc.

Compared to the single indicators, the construction process for Composite Indicators is highly sophisticated. That is why it is not easy to judge about the accuracy of Composites as interactions between the comprised indicators are possible. That is one of the biggest disadvantages of Composites.

An example for the construction of a composite indicator is shown in Equation (2.1). Let $y_{i,c}^t$ be the outcome of a single indicator i ($i = 1, \ldots, \nu$), of country c ($c = 1, \ldots, C$) at time t ($t = 1, \ldots, T$). A composite indicator can then be defined as a function of a set of single indicators:

$$\Psi_{c,t} = \Psi_{c,t}\left(y_{1,c}^t, y_{2,c}^t, \ldots, y_{\nu,c}^t\right) \tag{2.1}$$

The constituent single indicators are, in general, connected with a weighting scheme rather than a complex function. The weights can be equal or different for each indicator. If they are different, they can reflect characteristics of the data accordant like significance, reliability or others (FREUDENBERG 2003, p.12). One example to realize that is shown in Equation (2.2):

$$\Psi_{c,t} = w_{c,1} \cdot y_{c,1}^t \ldots \cdot w_{c,v} \cdot y_{c,v}^t \tag{2.2}$$

For this example the weighting scheme is realized by the different values for $w_{1,c} \ldots w_{v,c}$. An indicator with a weight closer to one has then an important influence on the composite indicator whereas an indicator with a value close to zero has a less important influence. In this case the sum $\sum_{i=1}^{v} w_v$ would equal for example 1. Different weighting schemes can have a big influence on the values for the composite indicator, therefore it is important to have a transparent explanation on the weighting methodology (FREUDENBERG 2003, p.12).

The steps realizing this composite have to be part of a quality analysis are:

1. Development of a theoretical framework
2. Selection of data
3. Multivariate analysis
4. Imputation of missing data
5. Normalization of data
6. Weighting and aggregation of data
7. Robustness and sensitivity analysis
8. Analysis of links to other variables
9. Deconstruction
10. Presentation and dissemination

The details of this process are described in deliverable 5.2 of the KEI project. The transparency of these steps is especially necessary as far as methodologies and basic data are concerned. The stages of development of the composite indicator have arbitrative influence on its quality (Thees 2007, p.2). To avoid risks, the *Handbook on Constructing Composite Indicators* (Nardo et al., 2005) puts special emphasis on documentation and on information about metadata.

When analyzing the ten steps above, the quality aspects are obvious. Each step is extremely important, but the coherence of the whole process is equally important. Choices made in one step can have important implications for other steps and might cause a reproduction of faults. Not only to make the most appropriate methodological choices in each step are crucial, but also to identify if they fit well together. To guaranty the quality of these steps, a well done reporting is essential.

One of the most well known composites with a well founded underlying model is the gross domestic product (GDP). It measures the total value of goods and services produced in a given country, where the weights are estimated based on economic theory and reflecting the relative price of goods and services. The theoretical and statistical framework to measure GDP has been developed over the last 50 years by the major international organisations. However, not all multi-dimensional concepts have such solid theoretical and empirical basis. For further examples of composite indicators see Saltelli (2007). As just mentioned for the evaluation of the single indicators, also the building of composite indicators might be very subjective. Especially in the newly emerging policy areas, like competitiveness, sustainable development, e-business readiness, etc. These issues are multidimensional phenomena, often they have been defined quite recently. The economic sociological and political research in these fields is still developing. This has to be considered when new indicators are designed.

Hence, again transparency is important to construct convincing indicators (Nardo et al. 2005, p.12). To face the multidimensionality of composite indicators, the different aspects from different disciplines assessed in a composite indicator, it is a good instrument to work interdisciplinary on the construction of new indicators. For example if issues covered concern employment, social cohesion and other aspects it is good to have different viewpoints on the same artifact (Münnich et al. 2006, p.2).

On of the first steps is to clarify which needs an indicator should satisfy. In a next step it should be checked to what extend essential conditions are satisfied to have reliable information. Several conditions are verbalized basically by Eurostat. These quality conditions will be presented partly in the next chapter. More information about the Pros and Cons of composite Indicators can be withdrawn from the KEI deliverable 5.1 (Saisana et al. 2005, pp.3).

Chapter 3

Quality concepts

The content of this chapter is closely connected with the content of workpackage 3.1. For the determination of the applicability of indicators the level of data quality is highly relevant. Due to the fact, that single indicators are the input of composites, the quality evaluation has to be decomposed into three aspects. Constitutive on the assessment of the data quality in general, the assessment of the quality of each single indicator has to take place. The aggregation of these two quality aspects leads to the quality measurement of the composite. Whereas the data quality in general is more about the availability of data one can account for more specific aspects in the data quality in case of single indicators. As there are, especially in context of this project, many countries to consider, naturally a multitude of different data sources have to be considered. The data comes from administrative, official and also private sources. Therefore it is not always easy to judge and compare the different underlying methods of collecting data.

3.1 Data quality as basis for indicator quality

When discussing the quality of composite indicator one needs to consider the quality of each single input, regarding the data and the indicators. A schematic illustration this proceeding is depicted in Figure 3.1. To evaluate the quality of a composite indicator Ψ the evaluation of the data quality has to be realized of the first stage. This is done by calculating a quality indicator D_i for each dataset which has to be considered when evaluating the single indicator quality by calculating the quality measure I_i.

As some of the quality dimensions for the data, as well as for indicators, are more important than other and a absence of one or another might be a knock-out criterion for the quality assessment, thus a weighting scheme of the dimensions is required. These results will be input for the quality evaluation of the real composite indicator. It is important to mention, that this concept, which is also presented in the following chart, is theoretically. The measurement of the single indicator quality as well as the one of the composite indicator has to be defined in future. Thus it is at least complicated to apply this kind of quality measurement for composite indicators. One also has to ask, if this kind of quality measurement will still offer the opportunity to make meaningful conclusions about the

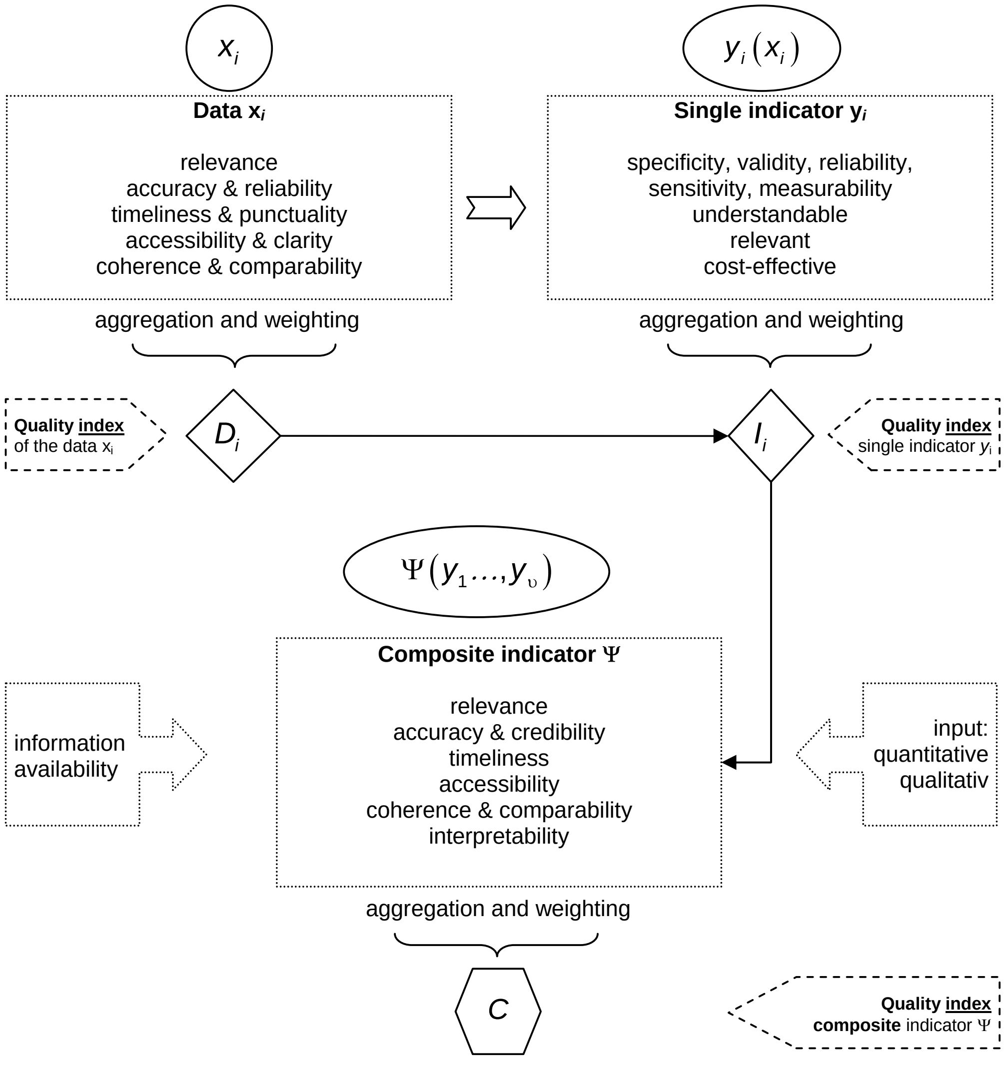


Figure 3.1: Overview - Quality for Composite Indicators

quality of the composite indicator or if the level of aggregation is too high. In fact if constructed, the indices D_i and I_i are composite indicators of quality.

The possibility of constructing a composite indicator and its significance for the quality is just discussed in Eurostat 2005a. The opinions concerning an overall quality indicator are differing, but it is concluded, that (Eurostat 2005b, p.21):

> „...an indicator could be helpful if developed to assess the overall quality of statistics provided by each Member State and then, aggregated to illustrate the overall quality of the information provided by all the Member States.“

The difficulty to construct such an indicator depends on the attributes of its components. The construction is comparatively simple if the indicators are quantitative. But from a conceptual and practical point of view it is often not so easy. Because many differences between countries as legislation differences, institutional settings and other sources of geographical incompatibilities have to be accounted for (Eurostat 2005b, p.21). Whereas Pre-defined standards for all the survey processes are not present or not followed in the Knowledge Economy context. This implies a political discussion about the weighting schema, comparable to the one for the general composite indicator. Even when calculated, a comparability over time would be difficult due to changes in the measurement process. In the EUROSTAT bulletin *Quality in Statistics* it is finally concluded, that (Eurostat 2005b, p.22):

> „...further developments are needed for defining a single meaningful indicator for each quality component (including guidelines for defining the weights), before this kind of indicator can be recommended for use. “

In addition the quality reporting is another problem for this kind of data quality assessment. Only a small number of the required standardized reports is published for the end user.

The so called *standard quality reports* (see e.g. Eurostat 2000b, Eurostat 2003d), do aim at covering general topics for the quality assessment. But they are implemented to different extents and with different practices in the member states.

Other examples are the *quality profiles* (cf. Eurostat 2000a or Eurostat 2003a). These do offer a detailed description of the indicators. Additionally the quality dimensions presented in Table 3.4 are considered. These profiles are intended for internal use therefore it is not possible for the end user to use these profiles aside some exceptions. The ones published (about 35 for structural indicators) consist of short and standardized descriptions. The commonly published quality information are *metadata*, they are a good source for informations concerning the quality if they do follow internationally agreed standards. One good example is the metadata comprised in the *NewCronos* database of Eurostat (cf. `http://epp.eurostat.ec.europa.eu`). The underlying Special Data Dissemination Standard consists of several dimensions (see Table 3.1). Due to its universality, Eurostat provides in addition a summarised methodology giving further information to the end user.

In fact, only one aspect is consistent with the existing quality indicators, which is the availability itself of the metadata (indicator AC3). In addition one can make a statement concerning the imputation rate (indicator A4) by analysing the availability of the data.

In addition to the discussed availability problem for the end user a scaling problem have to be kept in mind because an huge number of information is qualitative. Thus the calculation of a general quality measure becomes more difficult.

Under the assumption of having the possibility to calculate all data quality indices as well as the entire one for single indicators, the next step would be to impute the results in the assessment of the overall quality of the composite indicator. Thereby the weighting of each dataset and indicator have to be considered in the evaluation by using ideally the composite indicator function. Questions which have to be adressed in this context are the aggregation and weighting scheme to be used as well as the robustness and sensitivity of the results and their interpretation.

Base Page	**Summary Methodology**
General information - Geographic area - Statistical domain - Contact information	**Concepts, definitions & classifications** - Statistical concept - Definition of indicators - Classification system used
Dissemination formats (news releases, publications, on-line, databases, CD-Rom,...)	**Scope/coverage of the data** - Geographical coverage Statistical units Statistical population
Data - Data description - Time coverage - Periodicity - Timeliness	**Accounting conventions** - Reference period - Base period - Recording of transactions
Access - Dissemination of release calendar - Release procedures	**Nature of the basic data** - Data sources used - Type of survey - Techniques of data collection
Integrity (practices and procedures) - Rules on compilation and confidentiality - Access to data before release - Commentaries on data release - Revision and changes in methodologies	**Compilation practices** - Compilation of European aggregates - Adjustments - Data validation - Revision policy
Quality* - References to detailed methodology & sources - Related data bases and information - Quality framework and quality reports	**Other aspects** Special warnings

* A set of standards that deals with the coverage.

Table 3.1: Metadata published by Eurostat

3.2 Indicator Quality in the Knowledge Economy context

Parallel to the indicator definition also the data quality has to be defined. A good evidence for that purpose is the definition of the International Organisation for Standardisation (ISO) which is the approach to define principles of the quality management for dataset purposes. The ISO 9000:2000 definition shows, that the quality definition itself is a key issue, due to its multidimensional character (European Foundation for the Improvement of Living and Working Conditions 2007, §2):

> „Quality is a composite of all the characteristics, including performance, of an item, product or service that bears on its ability to satisfy stated or implied needs.“

Often this request is complemented by the demand to reduce costs and burden. For a better understanding of the problems implied by the multidimensional character of quality, the recent European quality discussion has to be drafted. This will point out a gap between the framework and definition of quality discussed and the information available for the end user for the assessment.

In 1999 a Leadership Group on Quality (LEG) was founded by the Statistical Program Committee (SPC) emphasizing the need of a common set of values for the European Statistical System (ESS). Its quality declaration, proclaiming (Grünewald and Linden 2001, p.7):

> „. . . to provide the European Union and the world with high quality information on the economy and society at the European, national and regional levels and make the information available to everyone for decision-making purposes, research and debate.“

Grünewald and Linden (2001) provide the basis for a quality framework (see also Leadership Group on Quality, 2001). For the first time the crucial role of quality reports also had been acknowledged (Eurostat, 2002).

The implementation of the quality declaration was realized in the beginning of 2005 by the implementation of the Code of Practice by Eurostat (Commission of the European Communities, 2005). Adopted by the SPC it also incorporates a quality definition with an institutional dimension, considering user and supplier aspects and provides a general framework for measuring quality through indicators. The Code aims at informing users about the trustworthiness of the statistics and the impartiality of the authorities having produced them. Additionally it aims at providing guarantees to data providers for the protection of confidential data and for limiting administrative burden. These aspects are summarized into three areas broken down into different principles (in brace). Thereby the latter refer to the quality dimensions to be considered:

- The institutional environment (professional independence, mandate for data collection, adequacy of resources, quality commitment, statistical confidentiality and impartiality and objectivity).

- The statistical processes (sound methodology, appropriate statistical procedures, non-excessive burden on respondents, cost effectiveness).
- The statistical output (relevance, accuracy and reliability, timeliness and punctuality, coherence and comparability, accessibility and clarity).

Overall, one can distinguish eight different quality dimensions (Table 3.2). Especially the last-mentioned dimension is crucial for the data quality. *Relevance* is for instance defined as the ability to satisfy recent and future user demands. It is about the question to which extend the definitions and classifications do reflect the user requirements(Eurostat, 2003a).

Whereas *accuracy* is the unbiasedness of estimators compared to the real value (MARRIOTT 1990, p. 223). The difference between the two values is the error. The following typology of errors are commonly adopted in statistics. At the on hand there are sampling errors they only do occur in sample survey context. These errors emerge from the fact that only a subset of the population, ideally randomly selected, can be captured. On the other hand non sampling errors do affect sample surveys as well as censuses or statistics derived from administrative registers. For these type of errors the sampling scheme is not important for their appearance.

Even though the objective is to assess the remaining bias of the output, some more process-oriented indicators are included. In this context, supportive quality indicators have been defined in order to measure the importance of key factors of non sampling errors. Three big categories of non sampling errors are known, these are the non response errors, the processing errors, and the coverage errors.

A second aspect embedded in this dimension is the *reliability* which is strongly connected with the issue of accuracy. As a matter of course results are only useable if the user can rely on the accuracy of estimations.

The *timeliness* of information reflects the length of time between its availability and the event or phenomenon it describes. Connected to this issue the *punctuality* refers to the time lag between the release date and the target date of delivery. It thus concerns the difference between the planned dissemination of the data and the effective dissemination. The target date might be defined by announcement in some official release calendar, determined by regulations or previously agreed among partners.

The next aspect, the *accessibility* refers to the physical conditions in which users can obtain data. Crucial questions here are where to go to get the data, how can data be ordered, when is the delivery time. It is important to take care about a clear pricing policy and convenient marketing conditions (copyright, etc.). Another important question is the matter of availability, if there is only macro or also micro data available and in which format the data is accessible. That is, if the data is only available in paper form, on a CDROM, or in a database in the Internet and which filetype is used to offer the data.

Clarity refers to the data's information environment whether data are accompanied with appropriate metadata, illustrations such as graphs and maps, and whether quality reports and information about limitations in use are included. Moreover it is also crucial to which extent additional assistance is provided by the responsible data provider (EUROSTAT 2003b, p.3).

Quality component	Indicator	Type
Relevance	R1. User satisfaction index	3
	R2. Rate of available statistics	1
Accuracy	A1. Coefficient of variation	1
	A2. Unit response rate (un-weighted/weighted)	2
	A3. Item response rate (un-weighted/weighted)	2
	A4. Imputation rate and ratio	2
	A5. Over-coverage and misclassification rates	2
	A6. Geographical under-coverage ratio	1
	A7. Average size of revisions	1
Timeliness and Punctuality	T1. Punctuality of time schedule of effective publication	1
	T2. Time lag between the end of reference period and the date of first results	1
	T3. Time lag between the end of reference period and the date of the final results	1
Accessibility and Clarity	AC1. Number of publications disseminated and/ or sold	1
	AC2. Number of accesses to databases	1
	AC3. Rate of completeness of metadata information for released statistics	3
Comparability	C1. Length of comparable time-series	1
	C2. Number of comparable time-series	1
	C3. Rate of differences in concepts and measurement from European norms	3
	C4. Asymmetries for statistics mirror flows	1
Coherence	CH1. Rate of statistics that satisfies the requirements for the main secondary use	3

Table 3.2: Data Quality

Source: Eurostat (2005c), p.3.

The *comparability* aims at measuring the impact of differences along time or in a regional context. Often it appears that statistical concepts and measurement tools applied differ between nations. Sometimes the type of the ascertainment changes in time as it was the case for the ECHP/EU-SILC example (Eurostat 2003a, p.62).

And finally the *coherence* of statistics concerns the adequacy. It should be possible to combine the data reliably in different ways and for various uses. It focuses on the joint use of statistics that are produced for different primary purposes. In general it is more complex to prove the coherence than to demonstrate cases of incoherence (Eurostat 2003b, p.3).

In addition to the LEG work and the implementation of the Code, a crucial role in the European quality discussion has been taken by the Working Group on the Assessment of Quality in Statistics founded by Eurostat in 1995. It mainly focuses on technical aspects of a quality implementation. It elaborates a quality definition (Eurostat, 2000b, Eurostat, 2000a, Eurostat, 2003b), a glossary (Eurostat, 2003c), and a methodology for quality reports (Eurostat, 2000b). An essential result was the elaboration of quality indicators to give the opportunity to assess the overall data quality (Eurostat, 2005c). Those indicators are also presented in Table 3.2. To measure the *relevance* of the data e.g., they propose the rate of availability. The indicators are distinguished into three types. Type one are key indicators, they representing the quality dimensions. Type two are supporting indicators to complete the quality evaluation and the last type of indicators are those, that need more development (EHLING and KÖRNER, 2007).

In summary the steps for evaluating the overall data quality, it might be possible to aggregate the computed single data quality indicators and to calculate a composite indicator of data quality.

Beside this European quality framework other well-known frameworks with other quality dimensions proposed exist. Among other the *Data Quality Assurance Framework* from the IMF (CARSON and BOORMAN, 2001) or the *Quality Framework and Guidelines for OECD Statistics* are to be mentioned here (OECD, 2003). The main difference concerns the quality dimensions applied (LALIBERTÉ et al., 2004), however the most frequently used ones are relevance, accuracy, timeliness, coherence, comparability and accessibility.

The quality of indicators, especially under the perspective of adequacy, is not jet evaluated in detail. De Vries elaborated a list of criteria relevant to guarantee indicators to be of good quality:

1. Policy-relevance: does the indicator provide a clear and unambiguous response to key policy issues and concerns?
2. Specificity: does the indicator have the capacity to measure only the phenomena for which it has been selected?
3. Validity: does the indicator actually measure what it has been chosen to measure; is it close enough to the reality being measured?
4. Reliability: is the indicator accurate and consistent, is it able to express the same message or yield the same conclusions if the measurement is carried out with different tools, by different people, in similar circumstances?
5. Sensitivity: does the indicator have the capacity to measure changes in the phenomena that it is intended to measure?
6. Measurability: is the indicator based on available data or feasible with respect to obtaining the required data?
7. User-friendliness: is the indicator comprehensible?
8. Cost-effectiveness: is the indicator worth the time and money it costs to produce it?

To make these principles more manageable, DE VRIES and WILLERN (2001) suggest to compress the criteria so that the following key aspects do result (DE VRIES and WILLERN, 2001, p.320). The first key aspect concerns the technically sound. This aspect is about the question, wether an indicator is well-defined, if it describes the phenomenon to be attended in an adequate manner. Furthermore the question is important if the indicator is robust. And finally the question if, it is technically possible to compile the statistics

	Indicators Quality Dimensions							
Data Quality Dimensions	Accuracy	Validity	Reliability	Sensitivity	Measurability	User-friendliness	Relevance	Cost-effective
Relevance	X	X		X	X		X	
Accuracy	X	X	X	X	X		X	
Timeliness and Punctuality						X		X
Accessibility and Clarity						X		X
Comparability			X		X		X	
Coherence	X	X	X	X	X		X	

Table 3.3: Interactions between Dimensions of Data and Indicators Quality

that are required to calculate the indicator. Here it is important that the measurement is reliably and repeatable.

The second key aspect concerns the comprehensibility of the constructed indicator. The connotation of the indicator should be easy to understand also for non-statisticians and especially policy makers. Therefore the indicator should be constructed in a way which is easy to explain. This topic is particularly relevant for composite indicators. The more composites there are thus the more synthetic an indicator is, the more difficult it will become to explain its value and meaning.

The third key aspect concerns the relevance of the indicator. That is about the question if the indicator is meaningful for policy makers and policy analysts. Before an indicator is constructed one should always clarify the use respectively the significance to the research topic.

The last key aspect concerns a more practical question. As the resources are often restricted, the Cost-effective plays an important role. This is namely the case for the development of indicators for developing countries. The researcher should always have the question in mind weather it is really worthwhile to try and compile the indicator.

Concerning the quality of indicators especially the trade off between data quality dimensions and indicator quality dimensions is important. Relationships between these two aspects are presented in Table 3.3.

One can see in Table 3.3 the relevance of data influences on the indicators quality and vice versa. In this Table the quality Dimensions introduced by EUROSTAT and presented in Workpackage 3.1 (Münnich et al., 2005, p.15) are contained.

One example can illustrate the coherence between data and indicator quality. Data, which do not have political relevance, can not be of relevance for a political indicator. Consequently, using not relevant data will also have implications for the accuracy and validity of the indicator. Changes which have to be measured can no longer be measured in this case, hence the sensitivity and the measurability of the indicator will also be effected.

Comparable conclusions can not be drawn in the case of inaccurate or incoherent data. In addition, the reliability will be effected, e.g. the error terms will be influenced. The implication of punctuality, timeliness, accessibility and clarity as well as comparability should be obvious.

Yet another not discussed aspect, is the one of measuring the quality aspects of indicators autonomous from the quality dimensions concerning the data quality. Thus further methodological discussions on this subject is necessary.

In the following a indicator is defined as y_c^t. Where c is the index for the country and t labels the point in time the indicator is collected. Whereas a set of indicators is defined as:

$$y_{i,c}^t \qquad \text{where} \quad i = 1, \ldots V \tag{3.1}$$

i is thus the index for every individual indicator, and V the number of observed indicators.

3.3 Composite Indicators Quality in the Knowledge Economy context

In the *Handbook on constructing composite indicators* (NARDO et al., 2005) the commonly used quality dimensions are discussed concerning their relevance for composite indicators. In fact, the quality dimensions to be considered are more or less the same just discussed for single indicator quality. But nevertheless some details have to be considered which are slightly different. The quality of a composite indicator depends strongly on the underlying variables. It is easier to mask data problems with a composite indicator (FREUDENBERG, 2003, p.8). It is possible to omit problematic variables. This affects the question of relevance of the indicator. As for the single indicator the variables should also be relevant for the phenomena being measured. And variables which are relevant shouldn't be omitted. As well as the should not have a negligible weight. For the visualization of composite indicators a wide range of techniques is applicable (SAISANA, 2008). The chosen one often influences the interpretation of the indicator. The visualization should then help to discover the relevance of the composite indicator.

In general it has to be considered that composite indicators can have methodological shortcomings. The quality of every single indicator comprised in the composite indicator has to be taken into account. That means that the worst performing indicator in quality has an influence on the quality as a whole. This causes a phenomena which can be denoted as a regression to the bottom. If the quality of one indicator is worse the quality of the composite also gets inferior. Contrariwise it is hard to upgrade the quality with some very good performing indicators. The interactions between the comprised indicators has to be checked. It is important to know in which way interactions do affect the accuracy of the composite indicator.

The interpretability and the credibility are dimensions which do gain in importance compared to the single indicator. Due to the aggregation process of a wide range of single indicators, the full interpretability of the composite indicator is eminent important quality requirement. The second aspect refers to the confidence that users place in those products based simply on their image of the data producer. Hence the trust in the objectivity is important.

When analyzing the quality of a composite indicator, the consideration of the construction phases is important, to receive an impression of the phases that do have the most important impact on the quality of the composite indicator. And also to know where the so far discussed quality of data and of the constituent indicators are most influencing. In the *Handbook on constructing composite indicators* (Nardo et al., 2005), the steps were opposed to the quality dimensions as shown in Table 3.4.

The second phase in the concept of constructing a composite indicator presented on page 8 is the data selection, or more precisely the indicator selection. In this phase the so far discussed quality aspects of data and indicators have the main influence. But also when evaluating the theoretical framework and during the other steps, the data and indicators will influence the quality of the composite.

	Quality Dimensions						
Construction Phase	Relevance	Accuracy	Credibility	Timeliness	Accessibility	Interpretability	Coherence
Theoretical framework	X		X			X	
Data selection	X	X	X	X			
Multivariate analysis		X	X			X	X
Missing data	X	X	X	X			
Normalisation		X	X			X	X
Weighting and aggregation	X	X	X			X	X
Robustness and sensitivity		X	X			X	
Other variables	X		X			X	X
Visualisation	X		X		X	X	
Deconstruction	X		X			X	
Dissemination	X		X		X	X	

Source: Phases of constructing a composite indicator according to Nardo et al., 2005

Table 3.4: Quality Dimensions of Composite Indicators

The exact measurement of the above mentioned quality dimensions is problematic. But comparable indicators to those of the quality dimensions are conceivable. In this case, the quality evaluation would also yield in a composite indicator of quality. Further reflection about a general applicable quality measurement concept of indicators will follow in the next chapter. Often constituent indicators merged by using a weighting scheme. To judge the quality of these composite indicators it is inalienable to conduct a sensitivity test.

This is done in Deliverable 5.5 of the KEI project. Normally it is not possible for the end user to distinguish between *real performance changes* and methodological changes or alterations in data coverage (FREUDENBERG, 2003, p.9). It is then appreciative to have information about the range in which changes due to the modification of the weighting scheme are possible.

Chapter 4

Quality of Knowledge Economy Indicators

In the previous chapter 3.1, some theoretic aspects of quality evaluation have been presented. It was mentioned, that the data quality plays an important role for the indicator quality. Altogether a wide range of categories has to be considered. One idea to take into account all these categories was to construct a composite indicator of quality measuring. As already stated close information is necessary to construct a composite. But as there is often no quality information available for the indicators it is difficult to construct such a measure. This is a general problem in the practical quality judgment for the Knowledge Economy Indicators and will be highlighted in the following chapter.

4.1 Data Sources

In the following the indicators, are divided in three groups. Indicators denoted with A reflect aspects which are in direct coherence with the Knowledge Economy. The indicator group B combines indicators with a more general character concerning the economic and social performance. The last indicator group signified with a C are indicators which deal with the globalization. An overview of the indicator groups is visible in Table 4.1

The indictors derive from different sources, administrative sources and private surveys, established as well as less known surveys. An overview of the used data sources is contained in Table 4.2. These surveys do differ in periodicity. The *Community Innovation Survey* for example is conducted every four years. It is therefore more complicated to construct annual indicators which are based on data from this survey. Other surveys are conducted every year like the German Micro-census. Another problem is the differing date of the first accomplishment and the partial big time lag between the accumulation and the dissemination of the data. Therefore it is difficult to fulfill the criteria of timeliness which is presented in Section 3.3.

A1 Production and diffusion of information and communication technology (ICT)	**A2 Human resources, skills and creativity**
Economic impact of ICT Internet use by firms Internet use by individuals Government ICT	General education Human resource in S&T education Skills Creativity Mobility
A3 Knowledge production and diffusion	**A4 Innovation, entrepreneurship and creative destruction**
Research and ex-perimen-tal development (R&D) Patents Bibliometrics Knowledge flows Total investment in intangibles	Entrepreneurship Demand for innovative products Financing of innovation Market innovation outputs Organisational indicators
B1 Economic outputs	**B2 Social performance**
Income Productivity Employment	Environmental Employment and economic welfare Quality of life indicators
Internationalisation	
Trade Knowledge production and diffusion Economic structure Human resources	

Table 4.1: Indicator groupes of the Knowledge Economy

Administrative data - European Statistics on Accidents at Work; Administrative sources
Annual Eurostat R&D questionnaires
Balance of Payments compilers: reports by the banking system on international transactions and direct surveys addressed to resident statistical units
Census / Micro-Census
Community Innovation Survey (CIS)
Continuing Vocational Training CVTS1 (year of reference 1993) CVTS2 (year of reference 1999)
European ICT surveys
European Union Labour Force Survey; Monthly indicator of the national unemployment delivered from the Member States
EU-SILC - European Community Household Panel
Joint UOE questionnaires on education statistics (UNESCO Institute of Statistics/OECD/Eurostat)
National R&D surveys and budgets; Common OECD/ESTAT Core questionnaire
Patent applications to the European Patent Office (EPO); Patents granted by the United States Patent and Trademark Office (USPTO); EPO's Worldwide Statistical Patent Database
OECD soureces: Pisa Survey, OECD database on Activities of Foreign Affiliates (AFA); OECD database on Technological Balance of Payments (TBP)
Structural Business Statistics
Various sources; Basic statistics come from many sources, including administrative data from government, censuses, and surveys of businesses and households / population registers, censuses, general or labour force surveys; Passenger surveys, and administrative sources
Other: Thomson ISI, SCI and SSCI; ipIQ, Inc., NSF, special tabulations; The Global Competitiveness Report 2004-2005; European Information Technology Observatory 2003 (EITO); European Values Study Survey; European Quality of Life Survey, web survey by the Capgemini
Statistical Business Registers
Other official sources: Five annual Joint Questionnaires of Eurostat and Energy Agency; FDI stock survey carried out by national banks and other surveys; European Environment Agency - data compilation based on the Convention on Climate Change; DG INFSOs

Table 4.2: Overview data sources

4.2 Data availability

One aspect, the data availability is shown in Figure 4.1. The figure shows the number of years for which data is available for every country considered in the project. For example it is necessary to have harmonized data, if several countries should be compared. These data should not disclose vacancies. On the top the abbreviations for the countries are depicted.

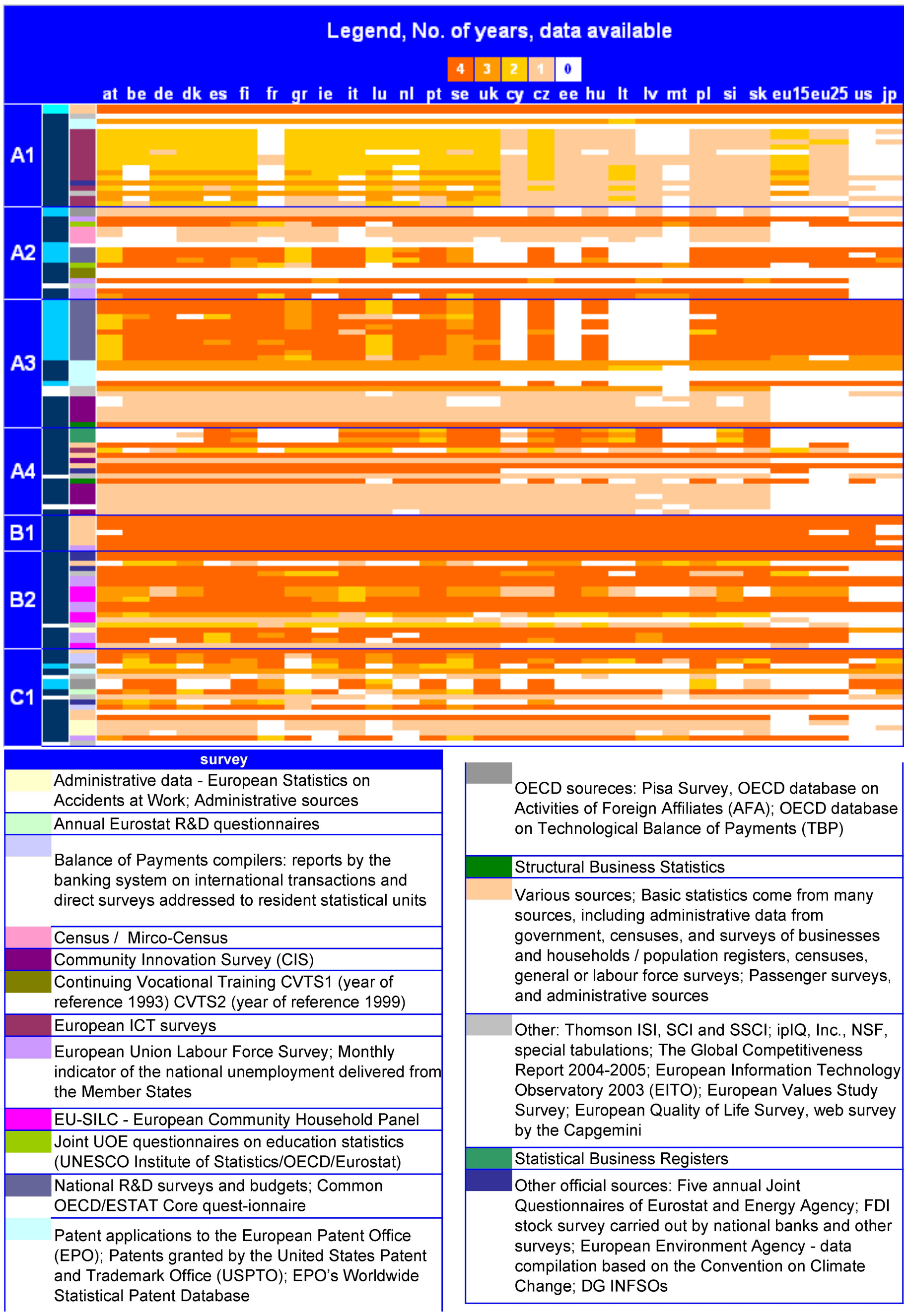


Figure 4.1: Data availability by country

Whereas the different indicators and indicator groups are drawn on the left hand side. Orange denotes a data availability for all four years of the evaluation period. Whereas white fields denote, that there is no data available for the years of the evaluation period. It is visible that the data availability differs more between the indicators than it does between the countries. The first two collum do display the data source thus the survey, from which the data is derived.

Especially for the newly evaluated aspects of group A1 (production and diffusion of ICT) the data availability is not high for the years of interest. Only for those of group B1 availability is given for all years, as the indicators are important and well implemented structural indicators, as e.g. the GDP. But in general it is evident that there are arbitrative cavities, especially if the data availability is accounted over four years. For 144 indicators only 125 data sets have been available. This number gets even smaller (116 datasets) if one checks the data availability over the whole evaluation period.

This example of the analysis of data availability and quality show that it is not possible to design a reliable composite quality indicator. And that it is even difficult to develop composite indicators which do not mislead in interpretation. Problems do occur from a quantitative as well as from a qualitative point of view. As there is also a lot of metadata lacking.

But here it has to be adverted on a special fact in the coherence of the Knowledge Economy context. It is obvious that a lot of new indicators are important for the Knowledge Economy. New means in this context the fact that the indicators have been developed in recent times to measure phenomena which started to occur in recently departed decades. It can be therefore expected that the survey design and hence the data quality gets better in future.

4.3 Metadata availability

A large single matrix was created to analyze the metadata availability in the knowledge economy context. This matrix comprehends for the first dimension 24 countries and values for the EU 15 and EU 25, in the second dimension 125 indicators and in the third dimension 96 quality levels. An overview of the different quality levels is provided in Figure A.1 in the appendix whereas an overview of the 125 indicators is comprehended in workpackage 2 of the KEI project. If information is available for a country, an indicator and a quality level, the cell in the matrix equals one and zero otherwise.

In addition a 97th quality level was created which shows the proportion of available quality levels over all indicators per country. This level indicates consequently the availability rate which is defined as the number of existent metadata dimensions in relation to the whole number of metadata dimensions in each dataset. This quality level shows the problem of the metadata availability. The value is not very high for any examined country despite for the EU 15 and EU 25 data. In Figure 4.2 it is visible that the average number of available quality levels per indicator lies about 7 quality levels.

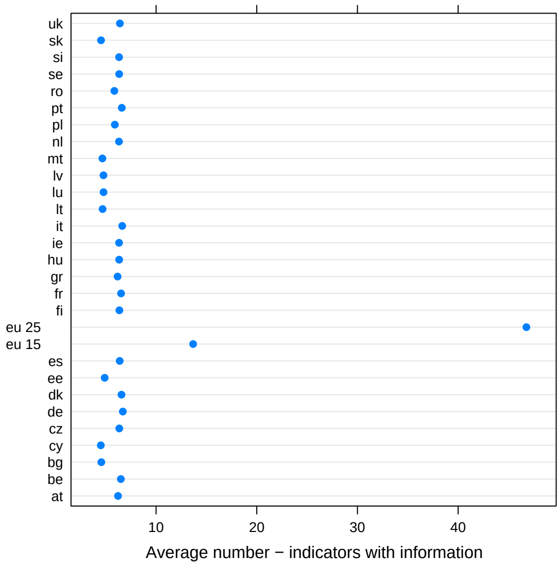


Figure 4.2: Average Number of dimensions with information available

The Spiderplot in Figure 4.3 the rate of quality information availability per indicator (Q97) can be seen for eu 25. Here it is visible how much the rate of availability differs between the indicator groups and also within this groups. The groups are separated form each other by wider spokes.

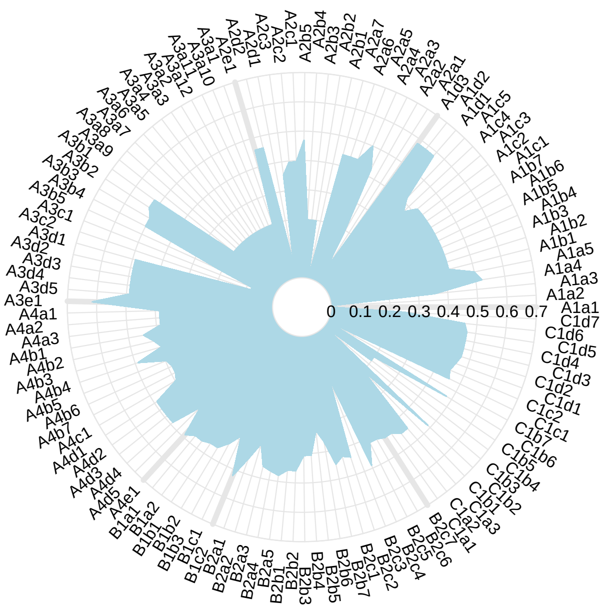


Figure 4.3: Availability of Metadata by indicator for eu 25

It attracts attention that the data quality is often at the same level for the different observed countries. The countries thus have a quite similar profile for the quality dimension availability which is visible in the spiderplots. Concerning the indicator A1b1 for instance only three levels of data availability do exist. As it can be seen in Figure 4.4 either there is no information available or the rate averages 13.5 percent basically in East-European countries and respectively 14.5 percent in West-European countries. In the following Figure 4.4 the countries are pigmented according to the rate of information available.

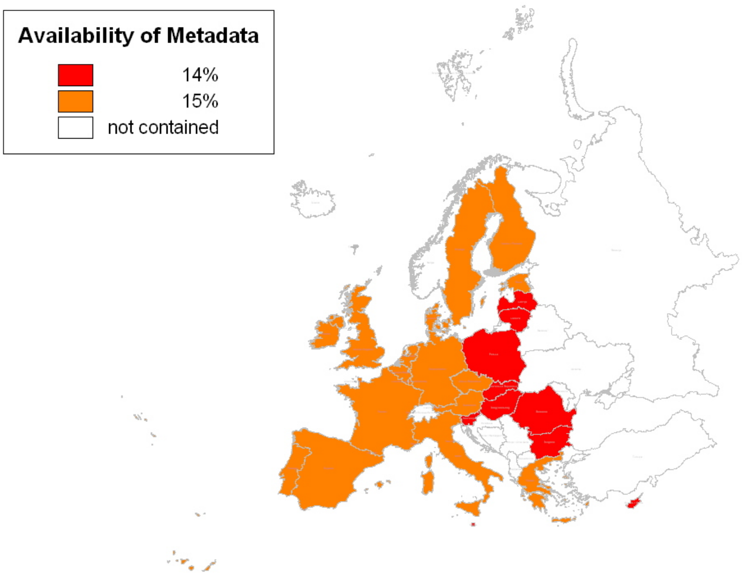
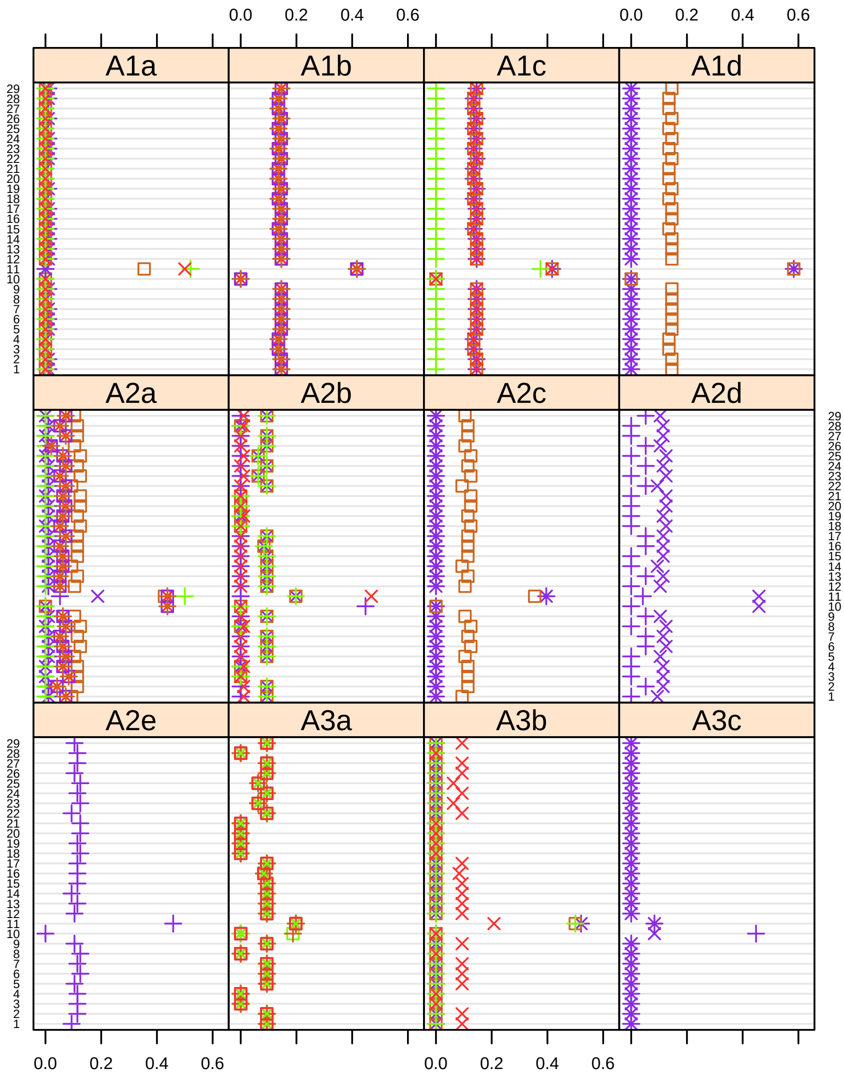


Figure 4.4: Availability of indicator *Businesses receiving orders over the Internet* by country

A comparable aspect is shown in Figures 4.5, 4.6, 4.7 here the rate of available quality levels Q97 is shown for all the countries and each indicator subgroup. Further on the quality level availability on indicator level is also visible. The different indicators are displayed by different symbols, which are visible in the legend. The seventh indicator in every indicator group is for example depicted by a brown cross. Most of the indicators with high rates for the quality level availability result from identical surveys. In group A1 the data result from the European Information and Communication Technology (ICT) survey.

In group A2 the indicators do result from censuses or from the Labour Force Survey. In the next group A3, the *main science and technology indicators (MSTI)* from the OECD have the highest rates. The availability levels for the indicator groups A1 to A3 are depicted in Figure 4.5. In these Figures it is also visible that the rate of availability is the same for the most indicators in one subgroup. Really different levels of availability for the quality metadata is only existing for the group A2a. For the other subgroups the level is either at zero or on one other level near zero. The only exception are the availability rates for the eu 15 and eu 25 which are depicted in every panel on the lines 10 and 11.



The numbers on the y-axis display the countries in alphabetical order, i.e. at be bg cy cz de dk ee es eu 15 eu 25 fi fr gr hu ie it lt lu lv mt nl pl pt ro se si sk uk.

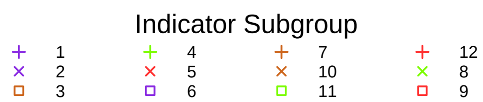


Figure 4.5: Indicators availability for indicator group A1-A3

The maximum rate over all is given by a population index of group A4, which comes from the registers. In all other groups, the indicator sources are the Labour Force Survey or EU-SILC. Some of the indicators in these groups have comparatively high values whereas there are also some indicators for which not any information on quality levels is available.

The indicators of group A1 have the best availability rates over all indicators. That is visible in Figure 4.5 where a big block with the metadata availability of 0,15 can be identified for the *Production and diffusion of information and communication technology (ICT)*. That means that there are 15 % of the possible information on metadata available. One reason for this phenomena might be that the data derive from the *European*

Information and Communication Technology Survey. These surveys are relatively new and the intension to pay attention on good documentation was implemented from the very beginning.

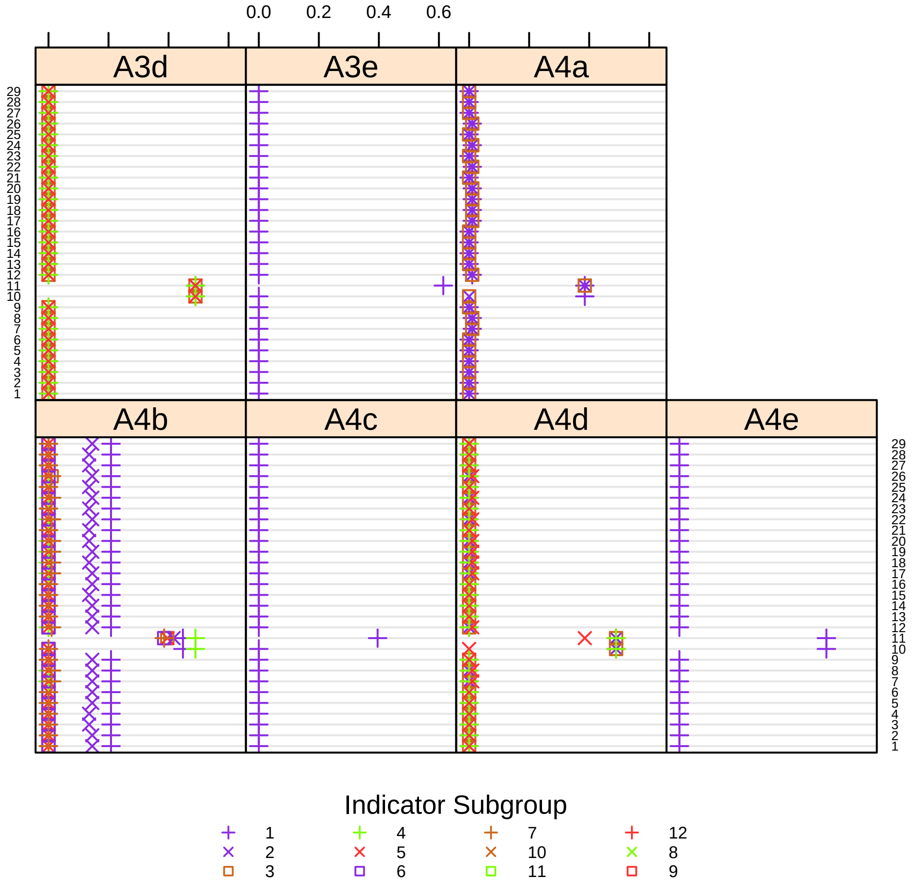


Figure 4.6: Indicators availability for indicator group A4

The subgroup B comprehends indicators concerning economic outputs and social performance (cf. Table 4.1 on p. 24) whereas the indicator subgroup C deals with the internationalization. As it can be seen in Figure 4.1 the data for these indicators result from from various but mainly official sources. Especially the sixth indicator in the subgroups B2b, B2c, C1a, C1d has a higher availability level which lies near 10 %.

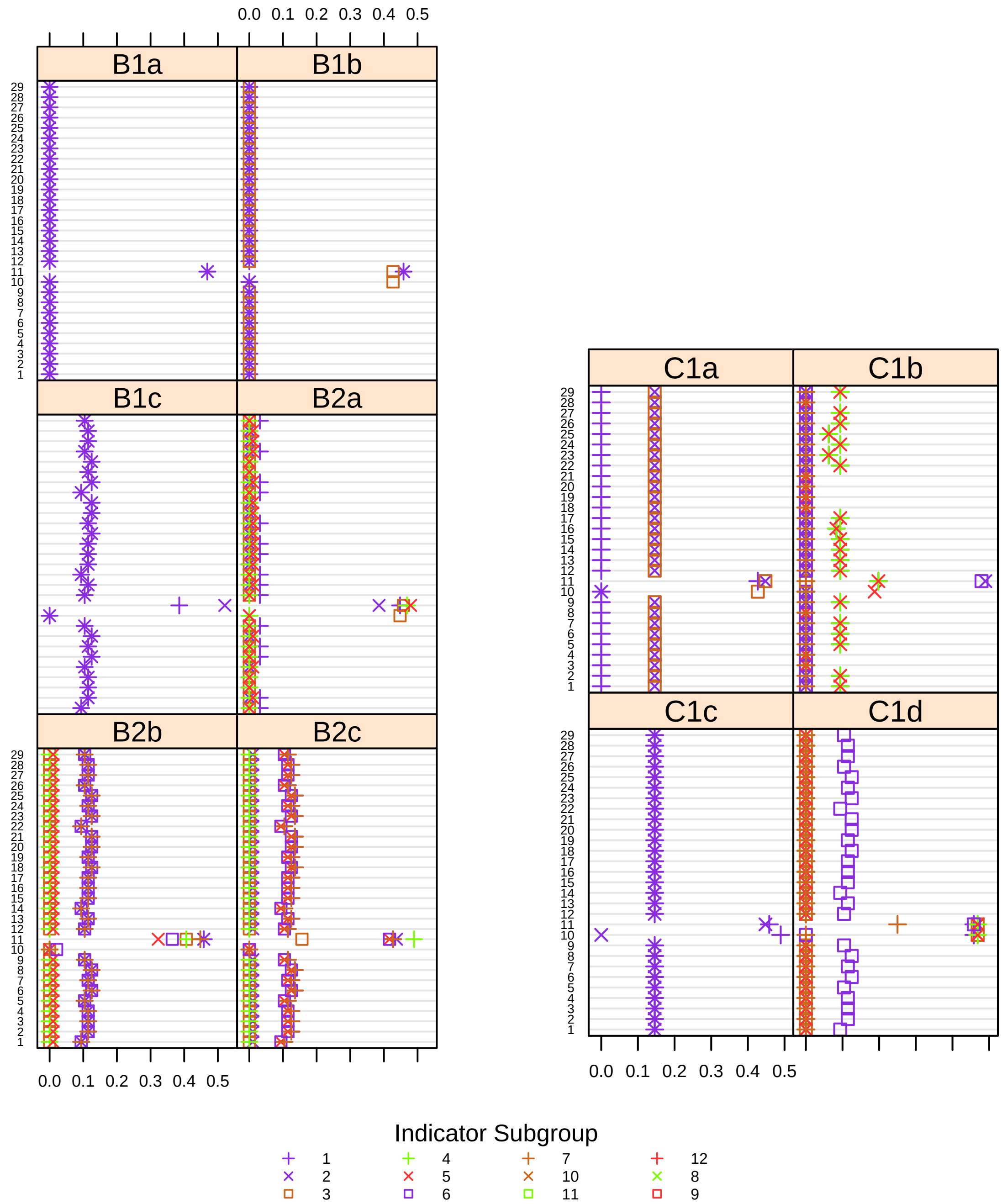


Figure 4.7: Indicators availability for indicator group B and C

Different aspects are important for the question of statistical reliability, which are displayed in one of the 96 quality levels. In the following some very important levels out of the 96 Quality levels have been chosen to show the problem of the metadata availability more precisely. Quality level 7 concerns the coverage of the data. Are there any coverage errors to be expected, is it likely to attend over- or undercoverage? These are important questions in that coherence. The question of regional coverage is an very important one and it is displayed in table 3.2 under the aspect of accuracy measurement.

The Quality level Q17 deals with statistical compilation rules. For this quality level the question is important wether information on those rules is available. The third quality level which is used in Figure 4.8 to illustrate the availability of metadata is Q18 which concerns the statistical confidentiality.

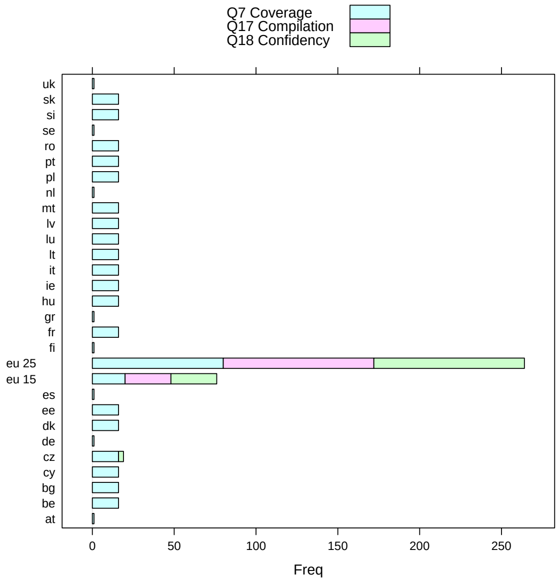


Figure 4.8: Metadata availability on statistical reliability

In Figure 4.8 it is visible, that the availability of information is strongly different between Europe as a whole and the individual countries. Apart from the available information for Europe, nearly no information is available for the compilation rules and the confidentiality. The situation is better for the coverage where information is available on some quality levels.

Concerning the accuracy of the data especially the quality levels *Standard Error-Q69, General Quality-Q83* and *Overall accuracy-Q91* are important. These quality levels are plotted exemplary in Figure 4.9. Here we have the same problem as with the information on statistical reliability. There is hardly any information available on these questions.

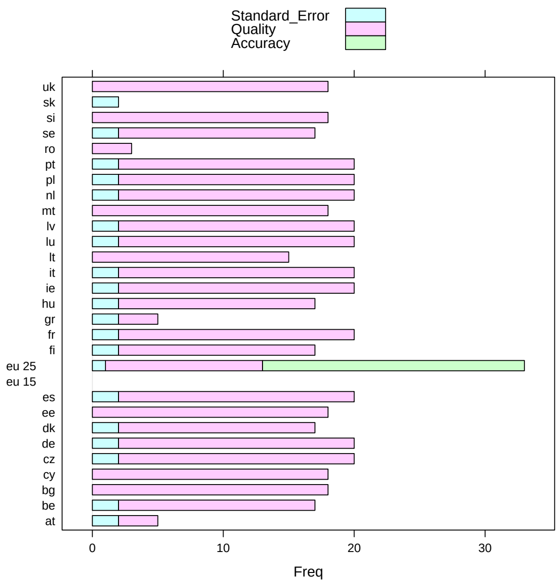


Figure 4.9: Metadata available on accuracy

In Figure 4.9 it is visible that often a indication concerning the standard error lacks. For some countries this information is missing all together for other countries there is information on some few quality levels. Therefore it is very complicated to make an assessment about the accuracy of the indicators.

These quality levels are just some examples, the whole list is shown in Table A.3 on page 42 in the Appendix and an overview about the number of indicators for which information is available on the quality levels per country is shown in Figure A.1 on 40 also in the Appendix.

Chapter 5

Conclusion

The aim of the present paper was to make an assessment of quality aspects focusing on their use for composite indicators in the Knowledge Economy. The idea was to develop a *composite indicator to measure the quality of a composite indicator*. One important question was to interpretability of this indicators. In order to adequately judge on the quality of a composite indicator first the quality of the underlying single indicators had to be evaluated. Possibilities and important items were shown in Chapters 3.1 and 3.2.

As shown in this report, the quality analysis for indicators as well as for composite indicators is hindered in case of the Knowledge Economy. Starting the analysis of the data quality of single and composite indicators coming from many sources still yields considerable problems, such as the availability rate of metadata and even the availability of the data its self. During the study it turned out that within the ESS many reports on metadata and quality are produced by the NSIs which, however, are hardly available to the public. The provision of metadata and quality reports is rapidly growing in amount of information and its quality. Eurostat and the NSIs are doing great effort to produce this information and to improve standards. This will surely help to overcome the difficulties that occurred within this study where little information was available in a very diverse format which was due to the inclusion of a wide variety of survey data. Within recent time researchers may expect to have aggregated data and information on these data in a standardized way with a high quality available.

Finally, further research on quality of single indicators, its measurement and impact on the quality of composite indicators will have to be done. Aspects like accuracy measurement for composite indicators respecting for missingness in data needs further attention, especially in the context of multi-survey data. Concerning the Knowledge Economy it seems very sophisticated to develop meaningful indicators with a reliable data basis due to the integration of many data sources. For the development of these indicators the comparability between different countries or regions as well as the consistent availability of data has to be guaranteed. The importance of composite will raise in future since they are already applied in many policy areas. With an increasing usage of such indicators in important areas it should be clear that high quality requirements are to be achieved.

Bibliography

Carson, C. S. and **Boorman, J.** (**2001**): *The 4th Review of the Fund's Data Standards' Initiatives. Supplement on the DQAF.*
URL http://www.imf.org/external/np/sta/dsbb/2001/070201.pdf

Cherchye, L., **Moesen, W.**, **Rogge, N.** and **van Puyenbroeck, T.** (**2007**): *An Introduction to 'benefit of the doubt' composite indicators.* In: Social Indicators Research, 82, S. 111–145.

Commission of the European Communities (**2005**): *Recommendation of the Commission on the independence, integrity and accountability of the national and Community statistical authorities COM(2005) 217 final.*
URL http://www.statbel.fgov.be/downloads/codstatback_en.pdf

Davey, J. (**1998**): *The Big Picture - Social Indicators and Social Change, in: Social Indicators in Assessment and Policy Development, Proceedings of the NZAIA (formerly ASA) Workshop Held at Wellington, 6TH November 1998.*
URL http://www.nzaia.org.nz/Conference/pre2002/Conf98.htm

de Vries and **Willern, F.** (**2001**): *Meaningful Measures: Indicators on Progress, Progress on Indicators.* In: International Statistical Review, 69, S. 313–331.

Ehling, M. and **Körner, T.** (**2007**): *Handbook on Data Quality Assessment - Methods and Tools.*
URL http://www.cmi.edu/research/rmi_government/EC/DatQAM_handbook_final.pdf

European Council (**2000**): *Presidency Conclusions - Lisbon European Council (DOC/00/8).*

European Foundation for the Improvement of Living and Working Conditions (**2007**): *Quality report of the 4th European working conditions survey.*
URL http://www.data-archive.ac.uk/doc/5639%5Cmrdoc%5Cpdf%5C5639userguide.pdf

Eurostat (**2000**a): *Definition of quality in statistics, Doc. Eurostat/A4/Quality/00/General/Definition.*
URL http://www.unece.org/stats/documents/2000/11/metis/crp.2.e.pdf

Eurostat (**2000**b): *Standard quality report. Document for the Working Party on the Assessment of Quality on Statistics. April 2000.*

Eurostat (**2002**): Quality in the European statistical system - The way forward. European Commission.
URL http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_DS_QUALITY/TAB47143266/ESS_QUALITY_RECOMMENDATIONS_2002_EN_0_1_0_0.PDF

Eurostat (**2003**a): *Handbook How to make a Quality Report.*
URL http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_DS_QUALITY/TAB47143233/HOWTOMAKEQUALITYREPORT_0.PDF

Eurostat (**2003**b): *Methodological documents - Definition of quality in statistics.*
URL http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_DS_QUALITY/TAB47141301/DEFINITION_2.PDF

Eurostat (**2003**c): *Methodological documents - glossary.*

Eurostat (**2003**d): *Standard quality report.*

Eurostat (**2005**a): *European Statistics Code of Practice.*

Eurostat (**2005**b): *Quality in Statistics.*
URL http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_DS_QUALITY/TAB47143233/STANDARD%20QUALITY%20INDICATORS.PDF

Eurostat (**2005**c): *Standard quality indicators, Doc. ESTAT/02/Quality/2005/9/Quality Indicators.*
URL http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_DS_QUALITY/TAB47143233/STANDARD%20QUALITY%20INDICATORS.PDF

Eurostat (**2008**): *Statistics of the week.*
URL http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2053,69416654&_dad=portal&_schema=PORTAL

Freudenberg, M. (**2003**): *Composite Indicators of Country Performance: A Critical Assessment.* In: OECD Science, Technology and Industry Working Papers, 2003/16, OECD Publishing.

Grünewald, W. and **Linden, H.** (**2001**): *Quality Measurement- EUROSTAT Expieriences.* In: Proceedings of Statistics Canada Symposium.
URL http://www.statcan.ca/english/freepub/11-522-XIE/2001001/session15/s15a.pdf

Laliberté, L., **Grünewald, W.** and **Probst, L.** (**2004**): *Data Quality: A Comparison of IMF's Data Quality Assessment Framework (DQAF) and the Eurostat's Quality Definition.*
URL http://dsbb.imf.org/vgn/images/pdfs/dqaf_eurostat.pdf

Leadership Group on Quality (**2001**): *Summary Report from the Leadership Group (LEG) on Quality.*
URL http://siqual.istat.it/files/LEGsummary.pdf?cod=8412&tipo=2

Marriott, F. (**1990**): A dictionary of statistical terms. Longman Scientific & Technical.

Menges, G. (**1972**): Grundriß der Statistik: Teil1: Theorie.

Münnich, R., **Åkerblom, M.**, **Magg, K.**, **Schmidt, K.**, **Wiegert, R.** and **Thees, N.** (**2005**): *KEI Workpackage 3 - Quality Concepts - State-of-the-Art.*

Münnich, R., **Thees, N.** and **Wiegert, R.** (**2006**): *Quality of knowlegde economy indicators.* In: Proceedings of Q2006 European Conference on Quality in Survey Statistics.

Munda, G. and **Nardo, M.** (**2005**): *Non-compensatory composite indicators for ranking countries: A defensible setting.* Technischer Bericht, Technical Report EUR 21833 EN, European Commission, Directorate-General Joint Research Centre, Institute for the Protection and Security of the Citizen.

Nardo, M., **Saisana, M.**, **Saltelli, A.**, **Tarantola, S.**, **Hoffman, A.** and **Giovannini, E.** (**2005**): *Handbook on constructing composite indicators: methodology and user guide.* In: OECD Statistics Working Paper.
URL `http://titania.sourceoecd.org/vl=9216248/cl=24/nw=1/rpsv/cgi-bin/wppdf?file=5lgmz9dkcdg4.pdf`

OECD (**2003**): *Quality Framework and Guidelines for OECD Statistical Activities.*

Régent, S. (**2002**): *The Open Method of Co-ordination: A supranational form of governance?*
URL `http://www.ilo.org/public/english/bureau/inst/download/dp13702.pdf`

Saisana, M. (**2008**): *Construction of Composite Indicators -Step 10 Visualisation.*
URL `http://composite-indicators.jrc.ec.europa.eu/S10_visualisation.htm`

Saisana, M., **Tarantola, S.**, **Schulze, N.**, **Cherchye, L.**, **Moesen, W.** and **Puyenbroeck., T. V.** (**2005**): *KEI Workpackage 5 - State-of-the-Art Report on Composite Indicators for the Knowledge-based Economy.* Technischer Bericht, Joint Research Centre, Ispra and KU Leuven.

Saltelli, A. (**2007**): *Composite Indicators between analysis and Advocacy.* In: Social Indicators Research, 81, S. 65–77.
URL `http://www.springerlink.com/content/87220m2m25253268/fulltext.pdf`

Thees, N. (**2007**): *Statistische Qualität zusammengesetzter Indikatoren am Beispiel der Wissensökonomie.* In: Gemeinsame Wissenschaftliche Kolloquien des Statistischen Bundesamtes und der Deutschen Statistischen Gesellschaft.
URL `http://kolloq.destatis.de/2007/thees.pdf`

v.d. Lippe, P. (**1990**): Wirtschaftsstatistik. Stuttgart: Gustav Fischer Verlag.

Appendix A

Availability of Metadata

In the following Figure the availability of information concerning the 96 quality levels is plotted. This quality levels do concern topics like coverage Q7 (an overview of all 97 contained quality levels is given in Figure A.3). They can be read on the x-axis from the left to the right, starting the Q1, Q2,... and so on. The KE Indicators can be read on the y-axis form the bottom to the top in a alphabetical order, strating with A1a1, A1a2,... and so on. If there is information on the topic the cell is signed with the value 1 otherwise it is 0. The levelplot embraces 12125 cells for every country which takes part in the analysis. If information is available for a certain indicator and the quality level the accordant cell is marked black. If there is no information available the cell is left white. Figure A.2 shows the same just in detail for eu 25, for which by fare is most quality information available.

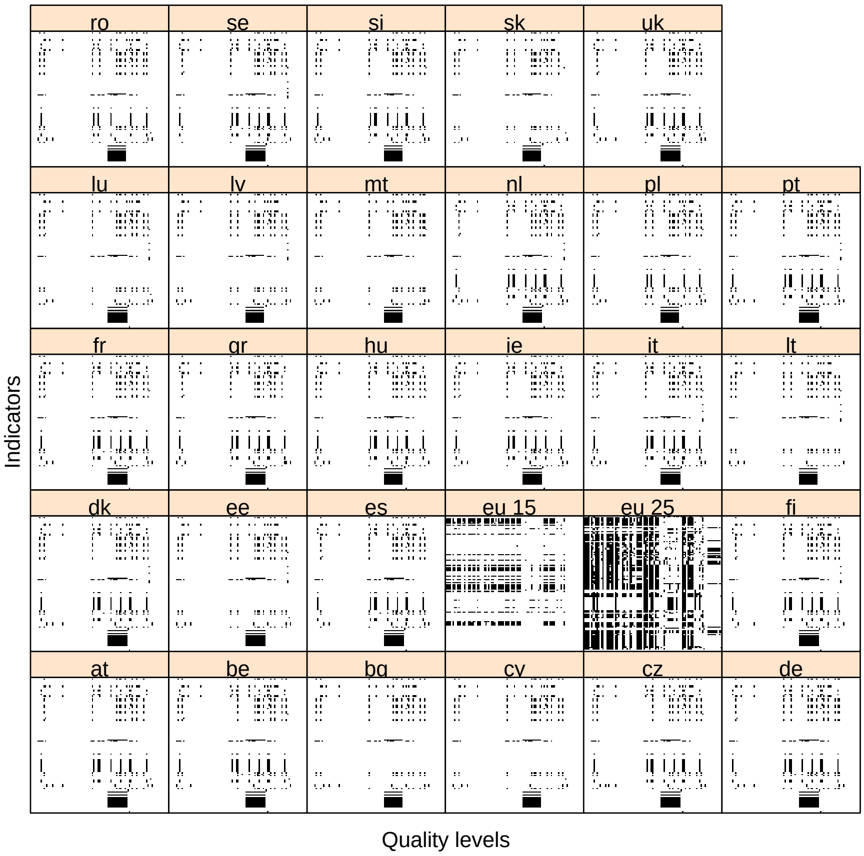


Figure A.1: Overview of quality levels by indicator and country

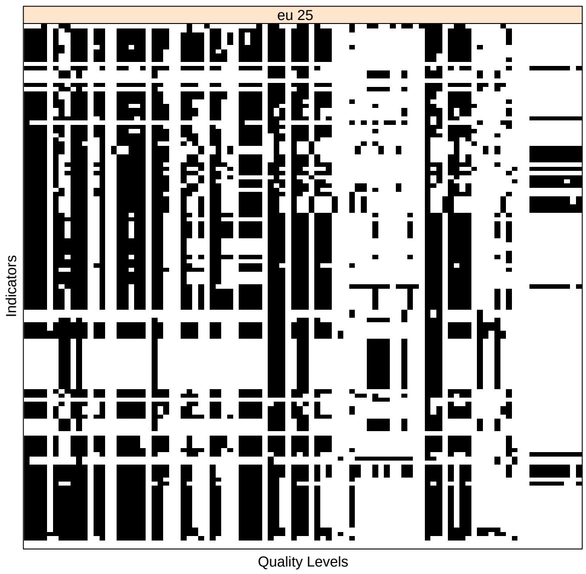


Figure A.2: Overview of quality levels by indicator for eu 25

Figure A.3 is an overview of all the 97 used quality levels. These levels are subdivided into different categories like general information, Coverage, Periodicity, Timeliness etc.

General information	Geographical area		1	Geographical area	Q1
	Data category		2	Data category	Q2
	Last update of this document		3	Last update of this document	Q3
	Contact		4	Contact	Q4
The Data: Coverage, Periodicity and Timeliness			5	The Data: Coverage, Periodicity and Timeliness	Q5
	Data characteristics		6	Data characteristics	Q6
		Coverage	7	Coverage	Q7
		Breakdowns	8	Breakdowns	Q8
		Time coverage	9	Time coverage	Q9
	Periodicity		10	Periodicity	Q10
	Timeliness		11	Timeliness	Q11
Access by the Public			12	Access by the Public	Q12
	Advance dissemination		13	Advance dissemination	Q13
	Simultaneous release		14	Simultaneous release	Q14
Integrity			15	Integrity	Q15
	Dissemination of terms and conditions		16	Dissemination of terms and conditions	Q16
		statistical compilation rules	17	statistical compilation rules	Q17
		statistical confidentiality	18	statistical confidentiality	Q18
	internal access to data before release		19	internal access to data before release	Q19
	commentary on the occasion of statistical releases		20	commentary on the occasion of statistical releases	Q20
	information about revision and changes in methodology		21	information about revision and changes in methodology	Q21
Quality			22	Quality	Q22
	documentation on methodology and types of data sources		23	documentation on methodology and types of data sources	Q23
	cross -checks, assurance of reasonableness		24	cross -checks, assurance of reasonableness	Q24
	Notes		25	Notes	Q25
Dissemination Formats			26	Dissemination Formats	Q26
	Hardcopy		27	Hardcopy	Q27
		News	28	News	Q28
		Publications	29	Publications	Q29
		More information	30	More information	Q30
		Other	31	Other	Q31
	Electronic		32	Electronic	Q32
		On -line or database	33	On -line or database	Q33
		Internet address	34	Internet address	Q34
		CD ROM	35	CD ROM	Q35
		Other	36	Other	Q36
Summary Methodology			37	Summary Methodology	Q37
	Geographical area		38	Geographical area	Q38
	Data category		39	Data category	Q39
	Last update of this document:		40	Last update of this document:	Q40
	Contact		41	Contact	Q41
Concepts, definitions and classification			42	Concepts, definitions and classifications	Q42
	Statistical concept		43	Statistical concept	Q43
	Definition of indicators		44	Definition of indicators	Q44
	Classification system and conformity with official standards		45	Classification system and conformity with official standards	Q45
Scope / coverage of the data			46	Scope / coverage of the data	Q46
	Geographical coverage		47	Geographical coverage	Q47
	Statistical units		48	Statistical units	Q48
	Statistical population		49	Statistical population	Q49
Accounting conventions			50	Accounting conventions	Q50
	Reference period		51	Reference period	Q51
	Base period		52	Base period	Q52
	Recording of transactions		53	Recording of transactions	Q53
Nature of the basic data			54	Nature of the basic data	Q54
	Year		55	Year	Q55
	Title		56	Title	Q56
	Organisation running the survey		57	Organisation running the survey	Q57
	Survey period		58	Survey period	Q58
	Reference period		59	Reference period	Q59
	Collection method		60	Collection method	Q60
	Population covered		61	Population covered	Q61
	Population size		62	Population size	Q62
	Sample size		63	Sample size	Q63
	Overall response rate		64	Overall response rate	Q64
	Main methodological differences compared to previous survey(s)		65	Main methodological differences compared to previous survey(s)	Q65
	Sampling and statistical methodology		66	Sampling and statistical methodology	Q66
	Stratification		67	Stratification	Q67
	Deviations from Eurostat model		68	Deviations from Eurostat model	Q68
	Standard Error		69	Standard Error	Q69
	Data sources used		70	Data sources used	Q70
	Type of survey		71	Type of survey	Q71
	Techniques of data collection		72	Techniques of data collection	Q72
Compilation practices (data processing)			73	Compilation practices (data processing)	Q73
	Compilation of European aggregates		74	Compilation of European aggregates	Q74
	Adjustments		75	Adjustments	Q75
	Data validation of statistical data		76	Data validation of statistical data	Q76
	Revision policy		77	Revision policy	Q77
Other aspects			78	Other aspects	Q78
	Methodological references		79	Methodological references	Q79
	Major changes in methodology		80	Major changes in methodology	Q80
	Universe covered		81	Universe covered	Q81
	Standardisation/comparability		82	Standardisation/comparability	Q82
	General Quality		83	General Quality	Q83
	Special Warning		84	Special Warning	Q84
Footnotes			85	Footnotes	Q85
			86	Footnotes	Q86
Quality report			87	Quality report	Q87
	Objective and relevance		88	Objective and relevance	Q88
	Data availability		89	Data availability	Q89
	assessment of accuracy and comparability		90	assessment of accuracy and comparability	Q90
	Overall accuracy		91	Overall accuracy	Q91
	Comparability across countries		92	Comparability across countries	Q92
	Comparability over time		93	Comparability over time	Q93
	Development perspective		94	Development perspective	Q94
	Contribution to quality for policy analysis		95	Contribution to quality for policy analysis	Q95
	Relevant European legislation		96	Relevant European legislation	Q96
				Total fraction of Info	Q97

Figure A.3: Overview of quality levels

Figure A.4 presents an overview of the average number of available quality levels for the Indicators. It is visible that this number does not vary much between the different countries. The average number is for any country higher than 5,4 %.

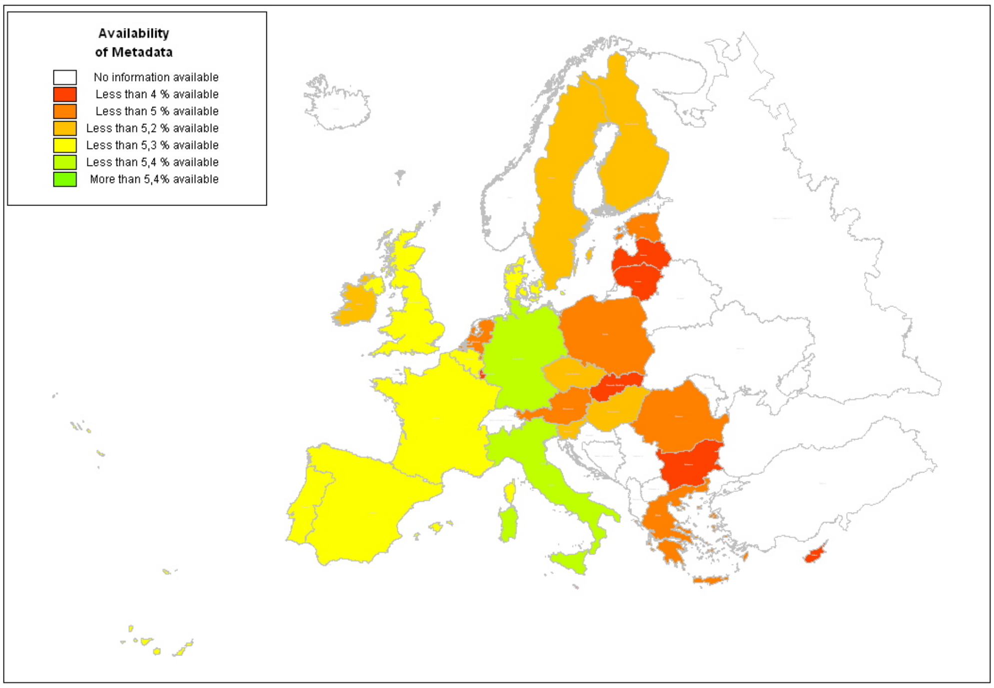


Figure A.4: Average number of Metadata Availability

Appendix B

Additional Information

In the following table B.1 the international codes are explained which are in use in the graphics.

Abbreviation	Country	Abbreviation	Country
at	Austria	lu	Luxembourg
be	Belgium	mt	Malta
dk	Denmark	pl	Poland
es	Spain	si	Slovenia
fi	Finland	sk	Slovakia
fr	France	eu 15	Europe 15 member states
gr	Greece	eu 25	Europe 25 member states
ie	Ireland	us	USA
it	Italy	jp	Japan

Table B.1: International country codes