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Determining Indicators of Quality of Life Differences in European Cities

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Determining Indicators of Quality of Life Differences in European Cities

by

Wolfgang Breuer* and Dominique Brueser+

Abstract. Comparing cities by the use of indicators representing numerous aspects of urban life is crucial to policy decisions, such as the funding allocation for urban development. Principal Component Analysis reveals a small number of indicators – from an initial set of 46 – which have a high impact on the overall differences between the selected cities of each of the ten countries, and five time frames that were analysed. Those selected indicators are spread over the initial groups, representing environmental, human, manufactured and social urban capital as well as demographic aspects. They cover current political debate on environmental, infrastructural and migration difficulties in cities, safety and especially security impairment stemming from anonymity and poverty in densely populated areas as well as population changes leading to space shortage in larger cities, or even abandonment in smaller cities. Furthermore, a second analysis reveals that the most important indicators for relative comparisons of possible funding targets depend on the geographic level (urban, regional, national) under consideration and thus the amount of funding for urban development should not be measured by regional or national indicator values.

JEL classifications code: Q01, R5

Keywords: urban differences, indicators, policy measures, funding efficiency

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1 Introduction

Urbanization is one of the most challenging aspects of our modern society. Nowadays, cities are both an engine of economic growth but also a locus of social problems. As approximately 80% of the European Union's population lives and works in urban areas, the regeneration of cities is an important issue for ensuring economic and social stability of the countries involved. Therefore, policy measures in the field of urban development for improving the quality of life in European cities have become more and more important over the last years. With the start of the 2006-2013 European Structural Funds Programming Period, the issue of urban development has reached a new dimension with the introduction of the JESSICA (Joint European Support for Sustainable Investments in City Areas) Initiative, which promotes sustainable development in urban areas through financial engineering instruments (see European Council, 2006a). Urban quality of life assessments are increasingly required as a basis for urban comparisons in order to build a sound foundation for policy decisions.

The European Regional Development Fund (ERDF) Operational Programmes (OPs) enforce, among others, European policy decisions for urban development. Accordingly, urban or regional comparisons are partly included in the determination of funding targets. Figure 1 gives an overview of methods applied for determining these targets, and this figure is an extended version of the findings of the European Commission (2008). Financial resources from the ERDF are currently proposed for investment in urban development by the use of two very different strategies, namely competition among specific projects, and the selection of cities as a whole. Announcements for the first strategy take place, e.g., in the OP of Brussels, Belgium. Within the second selection strategy we can observe two further distinctions, that of either a "subjective" or an "objective" selection. The former is circumscribed as a "black box", which means that we cannot reconstruct the process of selection. Again, there are two specifications. The first specification is that the OPs only provide the names of cities eligible for funding. This is, e.g., the case with the OP South-East of the Czech Republic. The OP names the two urbanisation centres, Brno and Jihlav, that should be supported through integrated urban development plans. The second specification is characterised by only providing the number of cities for funding. This is, e.g., the case for the OP Brandenburg, Germany: This OP states that, based on experiences of the URBAN-II initiative, 12 to 15 cities in this region should be supported.

<< Insert Figure 1 about here >>

Concerning the “objective” selection methods, there are mainly three different selection procedures, all of a quantitative nature. The first defines thresholds in order to determine cities eligible for funding. This is the case for the OP Andalusia, Spain, where cities with more than 50,000 inhabitants are most favourable for funding. The second procedure uses development indicators to determine cities for funding. In the OP Nord - Pas-de-Calais, France, we find that cities with a need for funding are determined by the three most poorly performing cities for each of a few indicators, e.g., unemployment and fiscal income. A third category of selection is characterised by defining different types of cities, e.g., cities which are regional growth poles (centres in polycentrical agglomerations) in the OPs of Romania.

The most promising way of funding determination for us is highlighted in Figure 1, which defines cities eligible for funding through objective data-based criteria that include development indicators. Our study adopts the general idea of employing indicators, but structurally identifies only a small number of indicators for quality of life comparisons of cities as a basis for policy decisions. Cities, therefore, should be compared by using a small number of meaningful measures, e.g., two indicators for the assessment of nonmonetary aspects covering quality of life aspects as shown in Figure 2. This figure reveals one possibility of comparing cities – represented by the points – on the basis of two indicators which define the axes. For this two-dimensional case, differences can be shown graphically and a benchmark can be set. This benchmark can then serve as the basis for measuring the need for urban development support by calculating the distance between each city and the benchmark in the two nonmonetary indicators.

<< Insert Figure 2 about here >>

However, the assessment of nonmonetary aspects always poses a problem. In the case of Figure 2, the definition of the two considered indicators is crucial to the results and their interpretation. The same holds true when applying other techniques for urban comparisons, such as the definition of one highly aggregated index, or the proposal of large indicator sets. These two extremes have their advantages and disadvantages. With respect to the first technique, difficult interpretations arise with single indexes (Mayer, 2008) when they cover multiple aspects, such as environment, manufacturing or demography. An aggregated approach for city comparison produces neat results and reflects extremes in the differences. However, values that do not clearly belong to the top or the bottom do not allow a solid statement, since the differences in the values of medium-ranked cities are comparatively small due to neutralisation effects in the aggregation. Consequently, interpreting the principal determinants and initial data that are responsible for the differences among the compared cities is not possible. In the current practice of regional development within the European Structural Funds, the main indicator for regional allocation of funding is not even aggregated; it is simply measured as the gross domestic product (European Council, 2006b). The latter approach – the definition of whole indicator sets – is a tedious task and results in a large number of indicators measuring the quality of life in cities. Therefore, handling all enclosed information objectively while maintaining all items of the initial description as well as the measurement of funding need are impossible using common methods. Hence, a trade-off between loss of information and interpretability is necessary. In the practice of European regional development policies, the targets for urban areas are defined in the ERDF Operational Programmes (see Figure 1). These documents include a broad analysis of regional differences, where often hundreds of indicators are considered. However, the final decision on funding targets for supporting neglected areas is often opaque on account of information overflow or a relatively small number of diverse indicators selected without justification, as already mentioned. Finally, as a middle course, frameworks that apply more sophisticated methods, such as multidimensional scaling or Principal Component Analysis (PCA), exist. These approaches reduce the complexity of the initial indicator sets to a smaller dimension that is larger than one by defining synthetically compressed indicators. Hence, these methods combine lower complexity with better clarification of a city's relative positioning. However, practitioners often tend to avoid such reduced framework approaches that are based on advanced mathematical methods, because the interpretation of the resulting compressed indicators is difficult. Our study aims at uncovering those indicators of an initial large set which are good representatives of the overall differences among cities, by employing PCA without the use of synthetic indicators. Our paper helps to determine funding targets through a complex method, yet without the disadvantages which might inhibit practical use. The revealing of clusters and the uncovering of disparities among countries or one country's regions through PCA is not new. However, this study analyses the influences of the initial indicators on the new composites in a broader way in order to reveal determinants of urban quality of life differences over a large sample of several countries, including cities and time frames. With our approach, we contribute to bridging the gap between the existing approaches of comparing cities using only one index on the one hand or by only considering some aspects of development on the other hand. In addition, our approach exceeds those that apply large sets of indicators with no specific methodology to reduce their complexity.

The optimal way would of course be to have a theoretical foundation for those indicators which have a high explanatory power for the differences among cities. Up to know, there is no established theory for this field of research and the development of such a theoretical basis seems to be impossible. That is why the only possible approach which is applied in this paper up to now is of empirical nature. Naturally, we check that the results are plausible in the context of covering all aspects of urban life and have been identified as important in the literature on urban development.

Afterwards, we add a second analysis enlarged to regional and national comparisons of possible funding targets. This reveals that the current practice of allocating money to regions and/or countries independently of the specific funding focus should be called into question.

This paper is structured as follows. The next section reviews the existing literature. Section 3 introduces PCA and the applied rotation technique. Section 4 presents the data and their selection criteria. Afterwards, the general structure of the analysis is shown in Section 5. Section 6 offers insights into the results of the analyses. Section 7 covers the three geographic units – cities, regions and countries – involved in the allocation of funding. Finally, Section 8 concludes by summarizing the results.

2 Literature review

This section aims at providing an overview of existing methodologies in the literature of urban quality of life differences. To completely cover current research approaches, this review also extends the slightly more general case of urban and regional development discrepancies.

First, there are some very specific approaches including only limited aspects of development for the comparison of cities and regions, such as that of Nijkamp (1986), who only concentrates on infrastructural influences. Another example is that of Callois and Aubert (2007). They empirically analyse the impact of social capital on regional development. A great advantage of such approaches is the limited number of variables included in the analyses. Hence, interpretation of the results is directly possible without the need for strong compressions.

The second type of literature related to this study consists of indexes for the measurement of quality of life and sustainability in general. Singh et al. (2009) give an overview of sustainable development indexes, which highlights that the application of PCA for the definition of indexes is not unusual. Li et al. (2006) and Soler- Rovira (2009) develop a synthetic index, but do not interpret the results in the context of sustainability aspects. Representatives of the missing interpretation of quality of life indexes are Slottje (1991) as well as Somarriba and Pena (2009). The strength of indexing is the clear ranking of items, but there is no possibility of in-depth interpretation. Mayer (2008) concludes that one index cannot cover the multidimensionality of sustainability. Parris and Kates (2003) state that the plurality nature of sustainable development inhibits a clear definition of one appropriate and interpretable index. Of course, both issues are equally true for the measurement of quality of life, as the topics are strongly connected (see Mitchel et al., 1995).

The third group consists of specific studies in the context of regional disparities uncovered by PCA and is thus not only methodologically but also object-orientated. This is done, e.g., for Portuguese regions by Oliveira Soares et al. (2003), for Greek regions by Monastiriotis (2007), for Turkish regions by Özaslan et al. (2006) and on a higher level for European countries by Tausch et al. (2007). In terms of methodology, indexing problems still arise, as proper interpretation of the new synthetic components is often missing, e.g., topic-related indicator clusters for the new components are not explained further and seem to be set up without any specific methods.

In the first group, which describes very specific approaches, the input for comparison is very limited, whereas in the other two groups of the literature, the output is very compressed and thus in-depth interpretation is problematic. This study will help to steer a middle course by identifying a small number of determining indicators for differences among cities. The input is a large indicator set and in this vein not limited, whereas the output is a small set of indicators, which are not compressed, so that interpretation is easily possible. In addition to the methodological contribution, our analysis covers ten countries and their cities (and regions), therefore not restricting the examination to one country's cities (or regions) or the comparison of countries as a whole.

3 Method

3.1 Principal Component Analysis for urban comparison

PCA transforms differences that are originally defined in a complex, multidimensional manner, as a large set of indicators, into a relatively small number of dimensions. Hence, it neatly arranges the objectives of comparison into a smaller dimensional space without any assumption on the indicators' distributions or their patterns of causality (Morrision, 1990).

PCA reduces the dimensions through a variance-maximising technique. It therefore maintains as much of the data's original variability as possible by reducing the complexity simultaneously. A new set of variables is generated by combining the initial indicators linearly. Each individual initial data point C_{il} for the i-th indicator value of the l-th city defines the position of the city explained through the transformed system $\overline{C}_{kl}$ as follows:

$$\overline{C}_{kl} = \sum_{i=1}^{n} P_{ki} \cdot C_{il}. \qquad (1)$$

The index i covers all integers with the maximum n, which equals the number of indicators. The loadings P_{ki} of the principal component P_k describe the linear transformation of the overall system for the k-th dimension. The principal components are determined stepwise while preserving the maximum possible information defined by the variability in the data. A useful feature of PCA is that the newly generated variables – the principal components – are ordered according to the amount of variance in the data which they describe (thus, according to their informational contents). By only considering the variables that capture the most part of the information, the number of variables to be further analysed is reduced and the index k stops with the reduced number of variables (denoted as r during the further procedure). Hence, the following inequality holds true for the reduced system:

$$r := \max k < n. \tag{2}$$

A comparison of cities by the two standardised indicators “highly educated proportion (female)” and “highly educated proportion” is exhibited in Figure 3. The original data points of the cities (shown as asterisks) lie approximately on the dashed line, representing the angle bisector. In this example, PCA determines a new variable, which is represented by the angle bisector – that expresses almost all the differences between cities in their relative positioning. The new data points for the compressed variable all lie on the angle bisector (printed as points in Figure 3). In this case, 99% of the original overall variance is captured by the new variable. Comparing Cologne and Bielefeld, the plot reveals that the distance of the original data points is approximately the same as the distance of the new points corresponding to these cities, as shown by the two bold lines of nearly the same length. In this special case, the new score for each city is calculated by the equally weighted sum of the two initial indicators. It is not necessary to separately analyse the two indicators for the relative comparison of the cities here, because PCA condenses this information in the new value with hardly any loss of information.

<< Insert Figure 3 about here>>

Normally, if considering more indicators, one new variable does not explain enough overall variance of the dataset. Then, additional new variables are determined in the same way as described above, with the further condition of being orthogonal – thus uncorrelated – to the previous ones. This results in a set of new variables – principal components – that explains the differences between the cities in lower dimensions. The number of principal components necessary to reproduce the differences of the cities depends on the desired accuracy. There are several criteria for the definition of boundaries to determine the new number of axes.

Finally, the influences of the original indicators – known as “factor loadings” – can be reconstructed to allow for analyses of the final positioning of cities and interpretation of the obtained principal components (Marques de Sá, 2007). As the factor loadings are often widely spread among the principal components, rotation methods help to overcome the resulting interpretation difficulties.

3.2 Rotation of the principal components for the identification of determining indicators

The aim of rotation techniques for obtained principal components is to find new axes that maintain the mathematical fit of the method and exhibit better interpretation opportunities. Each rotated principal component should have high factor loadings of some initial indicators, while the loadings of the other indicators are small. The result of a rotation is a set of new variables that have a high variation across the influences of the underlying indicators.

Figure 4 shows the influences of a set of five initial indicators on two principal components (namely, the compressed indicators 1 and 2) before (left plot) and after (right plot) rotation. The right plot reveals almost perfectly the identity of the new axes and the two bold initial indicators, while the others are unimportant for the differences among the compared cities. Hence, the factor loadings of these rotated principal components indicate the explanatory power of the urban audit indicators for the differences among cities, so that the positioning of the cities can be explained for each new dimension by only a few initial indicators. In the special case plotted in Figure 4, only one indicator explains each new dimension.

<< Insert Figure 4 about here >>

The rotation method employed in this paper is known as “varimax rotation”. It keeps the orthogonality of the axes and maximises the sum over all components’ variance of the squared loadings (Mulaik, 1972). This procedure is suitable for our application, because the principal components are almost uncorrelated, and thus orthogonal. To name one example, the average correlation between the principal components of each partial analysis, as implemented in Section 6.2, is only 0.09 with an even lower median of 0.07. In addition, the varimax rotation is the one out of the existing orthogonal rotations which helps best to interpret the resulting rotated principal components, which is exactly our aim (see Brosius, 2011).

4 Data

4.1 General data structure and categorisation

The data basis for this research study is the Urban Audit Key Indicator Set for core cities – the administrative unit of a city –, which is available as part of the Eurostat database. Generally, Urban Audit is a data collection of indicators to measure the quality of life in cities of the European Union, of candidate countries or of neighbouring countries. With this data collection, the DG Regio and Eurostat initiated a basis for a comparison necessary for policy measures on the urban level, which is exactly this study's approach. They defined criteria for one country's Urban Audit city selection, which include, e.g., a 20% proportion of inhabitants living in Urban Audit cities as well as geographic and size distributions (European Commission, 2009). The dataset for the analyses of this paper (downloaded on February 7th, 2012) consists of 30 countries – the EU 27 together with Turkey, Switzerland and Norway – with 372 urban units (counting some metropolitan areas as double units: one for the city and the other including the broader urban area). Table 1 shows the number of cities (# Units) taking part in the Urban Audit for each country.

<< Insert Table 1 about here >>

The data for each urban unit is available for different time frames. One time frame therefore defines only one data point. Its calculation differs depending on the original data availability (European Commission, 2009). The considered time frames here are: 1989-1993, 1994-1998, 1999-2002, 2003-2006, 2007-2009. For more details on country-specific definition differences and variations of reference years, see European Commission (2007b) and for general clarification of concepts, see European Commission (2004).

The key indicators cover several aspects of urban life quality. For our analyses, the indicators are newly categorised to maintain a more general and broader structure. Table 2 shows all indicators arranged by their categories.

<< Insert Table 2 about here >>

The demographic category covers all indicators of population size, changes and distribution. The other four categories represent Ekins and Medhurst's (2006) concept of "capital". Environmental (or natural) capital covers all natural aspects linked in a smaller or broader sense to human welfare, whereas manufactured capital describes produced assets which then help to produce goods and services. The last two categories are human and social capital. They refer to the well-being on an individual or societal level, respectively. Table 2 already reveals that the indicators are not equally distributed among the categories. Above all, manufactured and social capital have highly different extents. This abnormality does not only occur for the general category structure applied in this study, but also for Eurostat's own more detailed and differently arranged categorisation. It divides the indicators into demography, social aspects, economy, civic involvement, training and education, environment, travel and transport, information society as well as culture and recreation.

4.2 Data selection and final data availability for the study

Unfortunately, there are high variations on data availability across different cities and time frames, as revealed by an analysis for every combination of a country's cities and time frames. Therefore, a reduction of cities and time frames under consideration is necessary to take data gaps into account. We do so in such a way that remaining numbers of cities and time frames are as large as possible for the ten countries with the highest number of Urban Audit cities.

<< Insert Table 3 about here >>

Table 3 presents the resulting dataset. The abbreviation CR stands for the Czech Republic and UK for United Kingdom.

Furthermore, a minimum maximum standardisation technique adapts the data scales as a second step. Hence, any original data point x_i – with i =1, …, m, while m represents the number of cities from one country – for one indicator is transformed into

$$y_i = \frac{x_i - \min_j x_j}{\max_j x_j - \min_j x_j}, \text{ with } i, j = 1, \ldots, m. \qquad (3)$$

Before going into details on the analysis, we want to respond to some practical issues arising from data availability. Funding through the ERDF, which was our starting point, is defined for larger geographical scopes than cities. That is why the support of urban areas is mainly settled on a regional level for practical purposes. However, it is more likely that data on urban issues is not comparable across several regions from Europe and data gaps would be even higher. We thus concentrate on the city level with Urban Audit data, because it is already made conform by Eurostat and availability is high enough to conduct broad analyses. This constitutes an acceptable compromise in combination with the more limited regional and national studies which will follow in Section 7. Moreover, the section even reveals the necessity of urban considerations.

5 Analysis

The program MATLAB R2011b offers the main procedures for the overall computation of this study, which combines the mentioned standardization (see equation 3) with PCA and the varimax rotation method afterwards.

The aim of this study is to identify a small number of indicators which have a high impact on the overall differences between the Urban Audit cities of each of the analysed countries and time frames. Therefore, three decisions arise in each partial analysis: first, the definition of accuracy limits, second, the choice of a country, and third, the selection of a time frame. Our study covers six accuracy limits, ten countries and five time frames, which lead (after elimination of some datasets with low availability) to 244 partial analyses. The six accuracy limits consist of two preset limits. First, principal components need to explain at least 70%, 80% or 90% of overall variation in the data by inclusion of all principal components with explanatory power of at least 10% of the overall variation. These limits lie above the 60% limit, which is normally considered to be satisfactory in the context of PCA (see Oliveira

Soares et al., 2003). After this procedure, there remain only those r principal components for further calculations that exhibit the highest explanatory power. Second, the loadings P_{ki} with i = 1, …, n and k = 1, …,r after rotation (where n is the number of initial indicators and r is the number of components as defined in equation 2) should have at least a value of 0.3 or 0.4, respectively. This means that only indicators i with coefficients P_{ki} that are not smaller than 0.3 or 0.4 for minimum one k in the relationship revealed in equation 1 are further considered. Loadings P_{ki} not smaller than the limit of 0.3 or 0.4 fulfil the condition of being significant in explaining differences among cities for sample sizes of our study (Kline, 2002). In such a case, the indicator i is selected.

The results of each partial analysis are the selected indicators with a sufficiently high explanatory power regarding the differences between the cities under consideration. Afterwards, for each indicator, the percentage of situations (characterised by a certain accuracy limit, a certain country and a certain time frame) in which the respective indicator has been chosen, is calculated. Those indicators with the 20% highest proportion are then selected as determinants for urban differences, as a result of the overall analysis. Thereby, we define a limit which leads to the identification of a small set of nine indicators, thus steering a middle course between accuracy and manageability. In addition, this number is the maximum suitable one for further applications like the efficiency measurement of funding for typical sample sizes of one country's city comparison.

In addition, we conduct robustness and adaptability checks by determining the results for countries and time frames separately in a partial analysis. This allows us to test for country- and time-specific variations.

6 Results

6.1 Overall analysis for all time frames and cities of all countries

This part of the study reveals the overall explanatory power of indicators for urban quality of life differences by Urban Audit data for cities of ten countries and five time frames. Table 4 exhibits our results.

<< Insert Table 4 about here >>

The first and second columns describe the capital categories and the indicators. The subsequent columns contain the results (as the proportion of their selection compared to availability) of the calculations for all cities and time frames for the accuracy limits of 70% variance explained and 0.3 loadings after rotation, 70% and 0.4, 80% and 0.3, 80% and 0.4, 90% and 0.3 as well as 90% and 0.4, respectively. Thereby, we combine all of the low, medium and high limits, as defined and made plausible above. Finally, the last column shows the overall proportion of the indicator selection to its availability as mean over the different accuracy levels. The values of the upper quintile are darkly highlighted in each column. Even though the upper quintile usually consists of nine values, there might be more cells highlighted if multiple identical values lie on the lower quintile boundary. Our analysis reveals a good general alignment of the results for the different levels, with only some outliers. However, outliers mainly occur for the lower boundary of 0.3 for the principal component loadings. This can be explained by the fact that with these boundaries, compared to the case of 0.4 (with the same other accuracy limits), more indicators are selected. Then the variance of the corresponding proportions given in Table 4 is lower, so that small differences in the number of selections are already able to change those indicators being among the upper quintile – the darkly highlighted ones in the table. Hence, the 0.4 boundary better reflects the overall results in general, which will thus define the basis for the robustness checks in Section 6.2 with country and time variation. Considering all boundaries for the general selection leads to the following indicators in decreasing order:

- number of public transport stops per km^2,
- proportion of solid waste arising within the boundary processed by landfill,
- number of days where ozone concentration exceeds 120 µg/m^3 in Urban Audit cities as days per year,
- nationals born abroad as a proportion of total population,
- total population change over one year,
- female proportion of working age population qualified at level 5 or 6 ISCED,
- total annual population change over approximately five years,
- number of domestic burglaries per 1,000 inhabitants,

– car thefts in Urban Audit cities as number per 1,000 inhabitants.

They thus cover the fields of manufactured capital with public transport infrastructure, environmental capital with waste management and air quality, social capital with migration, safety and security, human capital with female education as well as demographic aspects with population changes (for the interpretation of all indicators, see European Commission, 2007a). Hence, the nine selected indicators are more or less equally spread among all aspects of urban quality of life, as covered by the initial set of 46 indicators. Thus, it is not necessary to compare cities by all initial indicators; instead, the set of nine is a sufficient selection of representatives.

A closer examination of possible reasons as to why indicators are not selected offers some interesting insights. There are two main factors which could explain this phenomenon. The first one is that indicators are similar among cities. As data is standardized, we are able to control for this reason by considering the difference between mean and median values for the respective indicator. If these two values are close, cities differ from each other, but the differences are equally spread among them. The explanatory power of such an equally spread indicator is not as high as it is when the mean and median value do not coincide at all. Such an indicator separates some cities from some others – it thus separates the good ones from the bad ones in terms of quality of life development. The second reason lies in one indicator's similarity to one of the selected indicators, because it is not necessary to look at both anymore, since one represents both of them. Now, comparing data with respect to those two aspects, we see that there is a tendency of unselected indicators to either have a low difference between the median and medium value or to have a high correlation with one of the selected indicators. By showing the irrelevance of some indicators for urban comparisons, studies like ours might question some political focuses. For example, employment and poverty indicators seem to be missing in our selection, although they are almost always mentioned in political debates. Our study reveals that problems in these fields either have quite a similar extension in one country's cities or that these indicators can be represented by one of the selected indicators.

Moreover, the nine indicators match current and recurrent political debate on environmental and infrastructural problems arising from urbanisation, migration difficulties in cities, safety, and especially security impairment due to anonymity and poverty in densely populated areas as well as population changes leading to space shortage in large cities, but also abandonment in smaller cities and rural regions. In addition, gender equality is always a topic of policies, and forms part of the selected indicators. Hence, the nine chosen indicators do not only satisfy analytical criteria, but also fit to the practical perception as well. However, an in-depth interpretation with a theoretical justification of the resulting small set is impossible. As urban and regional development are very complex in structure, there is no established theoretical foundation. This can also be seen indirectly by the high number of existing indicator sets which cover different indicators. Thus, the only way to justify our selection is to make them plausible as being important in the context of urban development with the help of other empirical research and perceptions. For the first indicator, there is empirical evidence that infrastructure has a positive influence on growth and income (see, e.g., Calderón and Servén, 2004). Moreover, the contribution of solid waste management to sustainable urban development has been mainly studied for developing countries revealing significant influences on the quality of life (see Baud et al., 2001). The impact of educational gender inequality on economic growth is also rather analysed for developing countries (Klasen, 2000). It is reasonable to assume that these two effects on urban wealth in Europe are less strong, but still prevalent. Greenhouse gases are also perceived as a relevant topic for urban development (see, e.g., Dodman, 2009). Reasons for population changes in European cities can be derived from quality of life differences as shown by Cheshire and Magrini (2006). Finally, del Frate and van Kesteren (2004) state that with increased urban life quality crime in cities decreases, thus approving the importance of urban security indicators. Furthermore, some aspects covered by the nine indicators also seem to have priorities for practitioners as well, because current EIB JESSICA agreements focus on, e.g., urban infrastructure and waste management.

6.2 Partial analysis

We check the robustness of the obtained results by examining the variations of selected indicators among the results for different time frames and countries. This is one feasible way to check for robustness when variations in data availability occur, as in our case. Comparing only those time frames and countries where at least all nine selected indicators are available would reduce the sample size to zero. Hence, in the following, we compare the results for partial analyses with time frame and country variation. Another kind of robustness check will follow in Section 7, where different geographic levels are analysed.

6.2.1 Time frame variation

We first analyse the time dependence of the indicator selection based on the rotated PCA. Table 5 shows the results of the 70% and 0.4 boundaries. The first column presents the indicators in the same order as in Table 4 (with the selected indicators in the first nine rows), and the following columns describe the proportion of selected indicators by the rotation loadings over data availability for the different time frames. The highlighted cells represent the values in the upper quintile of the respective column, and fonts in italics imply absence of any data.

<< Insert Table 5 about here >>

The analysis immediately reveals data availability problems for the first two time frames. In the first nine rows, the bundled absence of data is striking and reinforces the overall assumption that these indicators would also have been selected if data had been available. This finding is underpinned by the fact that for the other time frames, there are only two cases in the first nine rows where data are available but not selected. The two cases correspond to the indicators “proportion of solid waste arising within the boundary processed by landfill” for the time frame 1999-2002 and “female proportion of working age population qualified at level 5 or 6 ISCED” for the time frame 2007-2009. In every other case without selection, the data simply was not available and the missing blue shade is without meaning. Hence, better data availability is an unconditional requirement for the continuing use of Eurostat data for policy decisions.

Besides the aforementioned problems, the results show a number of consistencies. This means that indicators are selected for two subsequent time frames or only with a disruption of one period. Hence, there are 12 consistencies of the first type and, in addition, five indicators are selected again after a discontinuance of only one period. Seven of the 17 mentioned consistencies are represented by the selected nine indicators in the first rows. This fact indicates robustness of our results, when we compare it to the large overall time frame of 20 years, where development naturally influences quality of life determinants over time. Therefore, an application to policy decisions needs to maintain the possibility of accounting for changes in importance and for adopting time specific structures.

If the change and not the current relative position of a city in the development is the basis for a funding decision, the problem of time variation in the determining indicators becomes crucial. Then funding allocation is measured by comparing two subsequent time frames (which correspond to two single data points). One straightforward approach could be to only take the first year's selected indicators as the basis and compute their changes without considering all time frames, as we did before. Then the second reference point builds the new basis with its selected indicators for the measurement for the next two time frames. If the selected indicators for the two mentioned time frames change to a great extent, this could cause problems with long-term incentives enforced by policies on the European level. To prevent such circumstances, the indicator set should always be smoothened by defining the most important indicators over a number of former time frames plus a new one (in the way we did before, by selecting the indicators which are most often selected for all time frames). Thereby, the small set of selected indicators is adapted in a modest way to natural development changes, so that incentives are in line with these developments.

6.2.2 Country variation

A distribution analysis among the ten countries constitutes the second check for robustness. The structure, the boundaries and the presentation of results are the same as in the previous section, with the columns of Table 6 referring to the countries' results instead of time variations.

<< Insert Table 6 about here >>

Table 6 indicates that there are some countries with quite a high number of identical indicator selections among the upper quintile. The group of Spain, Turkey, and the UK each have six selected indicators in common. Another group consists of Poland, France, and Spain with five consistencies. Furthermore, Spain has five selections in common with Italy and the

UK with Romania. In addition, there are 14 further consistencies of four selected indicators. A cluster analysis with correlations as the distance metric and the unweighted average algorithm for the determination of distances between clusters now helps to objectively define groups of countries with similar indicators chosen among all values. Allowing for five clusters, the results are: a group of the Netherlands, Romania, Spain, Turkey, UK and a second group of France and Poland, whereas the other three countries – CR, Germany, Italy – define groups by themselves. Hence, the objectively conducted clusters correspond more or less to those obtained at first sight on only the upper quintile of values. The results suggest that there might be a need for country- or cluster-specific indicator sets.

The table indicates a high absence of data for the nine generally selected indicators, represented by the first rows, for some countries. This underpins the need for reliable data as mentioned above. This analysis again suggests that the first indicators would highly determine those countries' cities without data as well, because there are comparably few cases where data is available and the indicators are not chosen. Nevertheless, due to these data availability problems, we cannot guarantee robustness in every detail. In addition, it might not be suitable to simply have one indicator set to compare cities across all countries, but to have a specific indicator set for each country or clusters of certain countries, as indicated by the cluster analysis. However, one may take a look at the development regarding the above-listed nine key indicators for, e.g., different countries, and base quantitative funding decisions or efficiency analysis on this indicator set, but keeping in mind possible drawbacks.

7 Determining indicators for different geographical levels of comparison

Another issue mentioned before is the fact that independent of the funding aims the allocation of money is provided for regions only and not for, e.g., cities when urban development should be strengthened by a policy initiative. Hence, the development of the region is decisive for the amount of the resulting funding. Nevertheless, if funding has a specific aim, then the development of the respective field of interest and/or geographic unit should be the reference value for the public funds provided. In other words, if urban development should be supported, then the respective urban areas should be considered by urban indicators and not the regional development in general. However, the latter mechanism does not lead to the wrong funding decisions as long as the urban and regional development is similar in terms of the underlying indicators. Otherwise, the wrong targets are supported. This raises the question whether comparisons of cities and comparisons of regions can rely on the same set of indicators or whether the determining indicators differ from one level to another. In the following, we will determine the most important indicators from a large set for different levels of consideration (urban, regional, and national). This will reveal if the comparison of cities can be made by the same indicators as the comparisons of regions or countries in terms of urban development support.

7.1 Reduced initial indicator sets

7.1.1 Data availability for all levels

The basis for the analyses is the same indicator set as before when we analysed a set of size 46 for the urban level. Data for regions and countries is not provided for the set of Urban Audit Indicators in a compressed way as it is for cities. Hence, we collected it from several datasheets of the Eurostat database and partly computed the values on the basis of other indicators (e.g., for population change over five years). The countries are the same as before for national and regional comparisons except for Turkey where national data is not provided sufficiently. The time frames begin in 1994, end in 2010 and are made compatible with the one of the Urban Audit. Nevertheless, not all of the Urban Audit indicators could be collected for regions and countries. To ensure comparability in the following analyses, a reduced set of initial indicators is the basis for the comparison among different levels. From the 46 initial indicators, only 21 are available for all three levels. Regions have the lowest number of indicators (21) and countries have a medium number (36) available. Table 7 reveals the resulting set of 21 indicators in the second column. The first column describes the respective category as defined before.

<<< Insert Table 7 about here >>>

Comparing this set to the larger one listed in Table 2, it strikes that especially the indicators from the social capital category are not collected for all levels, i.e., only three of the 22 social indicators are left in the set, which is now the basis for the comparison of the three levels.

On the contrary, all other categories are still represented by at least 70 % remaining indicators (demographic: 80 %, environmental: 75 %, human: 70 %, and manufactured: 100 %). These facts strongly change the weighting of the set, which is used as input for the PCA. Hence, before we start analysing the differences among the three levels, we have to check whether the method is robust for changes in the input set, first.

7.1.2 Robustness for changes in the initial set

So far, the analysis of robustness (see Section 6.2) left out the variation of the initial set. For the sake of completeness and to evaluate the restriction of having only 21 indicators as input for the PCA, if we want to compare the results for all levels, we will now add such an analysis for cities and countries. For cities we compare the results from the PCA with rotation with an input set of size 46 on the one hand and 21 on the other hand. For countries, the two input sets consist of either 36 or 21 indicators. For regions, we refrain from lowering the size of the set as we only have 21 indicators available.

First, we conduct the same analyses as before for cities (with the same barriers as in Section 5), but with the 21 indicators from Table 7 as input. To be able to compare the results to those with an input set of size 46, we delete the other 25 indicators of the PCA and rotation (for all barriers), and integrate them together with the results for the computation with only 21 indicators in one table (see Table 8). We define two categories of importance: If the indicators are among the first third of the 21 rested ones (for both input sets), they are marked with an "X" and highlighted in dark, representing importance in describing differences among the compared cities. If they are among the other two thirds, they remain without shading and "X", demonstrating their insignificance. A further distinction by their specific position in the listings is not intended: The indicators are only listed by those two categories in Table 8, but the order within the categories is not maintained for sake of clarity of the overall comparison. We set the highest third as barrier as a compromise between the quintile and the absolute number of nine which defined the selection criteria for cities before and seemed to be manageable for practical applications.

<<< Insert Table 8 about here >>>

This representation reveals that the method is partly dependent on the size of the initial indicator set. However, the majority of the most important (darkly highlighted) indicators defined by the last two columns are the same if the limit of importance is set to the first third of the remaining 21 indicators ranked by the analysis based on 21 or 46 indicators, respectively. The five indicators of the first rows remain important independent of the range of the initial set. The variation only covers two indicators for each input set and the exchanged indicators are very similar in their meaning. The former is also true for the comparison of countries with either 21 or all 36 available indicators. Table 9 demonstrates the respective results. Again, five of the most important indicators remain the same and no more than two differ for each initial set. However, the slight change this time is more substantial.

<<< Insert Table 9 about here >>>

Most interestingly, the dependence of education indicators on the input set is present and has the same extent for both levels – cities and regions. We thus see that it is important to be aware of this fact, because it can slightly change the results if funding decisions are based on the value of some indicators. This deviation is a disadvantage of the idea to employ a small set as representative and is explainable through the limits we set to determine the selection of an indicator in our specific method. If we take another set as basis, the proportion of one coefficient can fall below the limits for some evaluations of the differences among the cities or countries, respectively. Thus, the overall selection can slightly change for different underlying indicator sets and this will always be an issue for any similar method. Defining other limits for the selection would not help to overcome this drawback, but only shift it to another barrier. However, we showed that the results remain the same in the majority, which demonstrates the general validity of the method. Hence, for the application of our selection method, the advantages and drawbacks of such a simplification should be carefully weighted depending on the underlying situation.

7.2 Selected indicators for the urban, regional and national level

As a result of the former analysis, we do not compare the selected indicators for the different levels with the maximum initial indicators available per level, but we take the same set as basis for our computations in order to exclude method-based changes and get reliable results. Thus, we take the set of 21 indicators listed in Table 7 as basis for the comparison of important indicators for cities, regions, and countries individually. Then, we conduct a PCA with rotation for each level (with the other parameters as described in Section 5). Table 10 shows the resulting selections for all levels. Dark markings reveal the importance for the respective comparisons.

<<< Insert Table 10 about here >>>

In contrast to Table 8 and Table 9, the darkly highlighted cells now differ to a much greater extent. Only one of the seven most important indicators (from the initial set of size 21), namely “Total population”, for cities is also selected for all levels and an additional one for each regions – “Proportion of working age population at level 1 or 2 ISCED female” – and countries – Number of stops of public transport per km². Furthermore, only three indicators are selected for their suitability to compare regions or countries: “Total population”, “Total population at working age” and “Tourist overnight stays in registered accommodation as number of nights per year”. As the input set for all three levels is the same, the resulting deviations cannot be explained by the limits of selection within the method. This time, the changes come from the differences in the variations among the indicators for the scales of consideration (urban, regional or national). Those differences seem plausible if we consider them in more detail.

“Total population change over one year” is, e.g., highly diverging among cities. However, for regions and countries the relative differences in population change are less important. The fact that people often move, but still keep their workplace, strengthens the assumption that they stay within their region (and country) and just relocate their personal residence to a city or county nearby. In addition, the higher the aggregation level, the higher is the probability of having compensatory effects from those people that are moving in and those that are leaving the geographic unit. Such compensations are also realistic for, e.g., unemployment rates. The unemployment rate for cities is more diverse than it is for regions and countries. It is unrealistic that all areas in one region or country suffer from the same high unemployment. However, locally concentrated spots (individual cities) with employment issues are typical. Other data published by, e.g., the German “Bundesagentur für Arbeit” support this thesis; the spread of averaged unemployment rates among regions in 2012 is 8.6 percentage points, whereas the spread among cities/counties is 14.4 percentage points and thus much higher which reveals the higher heterogeneity on lower geographical levels due to the absence of neutralisation effects.

In contrast, “Total population at working age” differs more for regions and countries than it does for cities. As cities are often more attractive for young professionals in general (see Peri, 2001), and too expensive for families, the latter leave within their working life and typically do not move back as pensioners due to emotional or material commitment. These two effects of having families and pensioners living rather in rural areas are the reasons for a high homogeneity of working age population in cities on the one hand and a high heterogeneity in regions and countries on the other hand. The indicator “Population in part-time employment” is just important for the comparison of countries and not for the lower levels. This might be due to cultural differences in combining work and family as well as traditional ways of life in the respective environment. And as culture is the same or at least very similar for regions and cities of one country, the differences are only relevant for the comparison at the highest level, because it is a strong commitment device for staying within one country according to Cheshire and Magrini (2006).

To conclude, we saw that the meaningful indicators to describe the relative situation among possible funding targets of a specific geographic unit are not the same for the three levels under consideration. Therefore, the selection of indicators for, e.g., funding allocation should be carefully conducted with respect to the aim of support and especially the geographical scope, because it is not advisable to take the same indicators for all purposes and levels. Hence, the allocation of urban development funding should base on urban indicators measured for cities.

8 Conclusion

This study used PCA with a subsequent rotation technique to identify a small number of indicators that adequately represent urban quality of life differences among one country’s cities. Furthermore, we provide several robustness checks and derive application conditions as well as data requirements. Moreover, we compared selections of urban development indicators measured for three geographic units – cities, regions, and countries.

The overall analysis points out that a small indicator set of nine items determines the differences among one country's cities for several boundaries, countries, and time frames. This small set of indicators helps to steer a middle course between the findings in the literature by combining several fields of urban development and refraining from only considering one compressed indicator without interpretation opportunities for only one country's cities. The results are plausible in the context of current political debate, as the set covers nearly all policy aspects of urban life. Additionally, in the context of methodology, the selections do not vary much when the boundaries are changed. However, the general application of a small indicator set needs to be controlled over time and space. It might be advisable to consider cluster-specific indicator sets, depending on data and the decision problem at hand. These could then result from the concerned countries' PCA with rotation, in the same manner as described in this study. In addition, politicians should be aware of the dependence of relative indicator values on the underlying geographic level. Thus, the input sets for comparisons and the geographic unit measured need to be carefully adjusted to the respective policy aim.

The general motivation of this paper is covered in the overall analysis. The more detailed parts of the study reveal problems arising from data availability that weaken its robustness and from geographic dependencies. However, the results are generally plausible from a methodological and practical point of view, and applying this method to wider data sets with more time frames and units seems promising. This analysis may lead to important insights, which could impact policy measures on urban development with its processes of funding allocation as well as similar fields.

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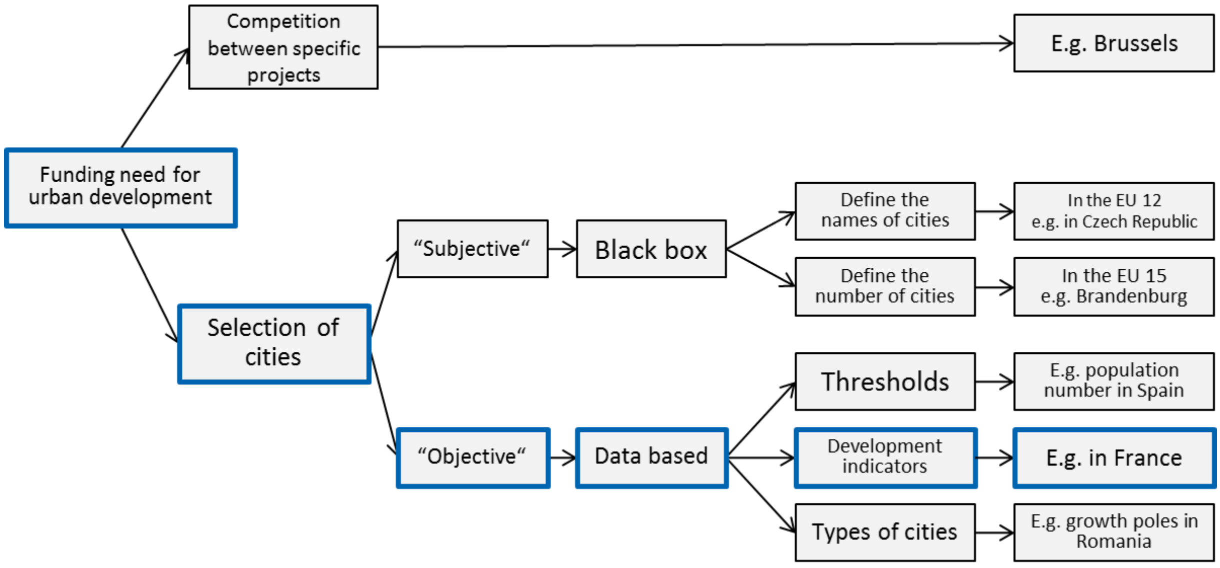

Figure 1: Funding target determination in the ERDF Operational Programmes of the current Programming Period 2007-2013

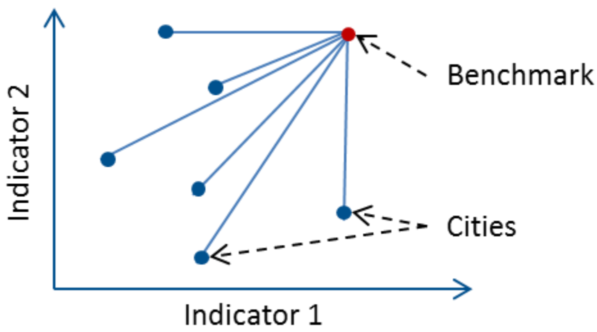

Figure 2: City comparison for funding target determination.

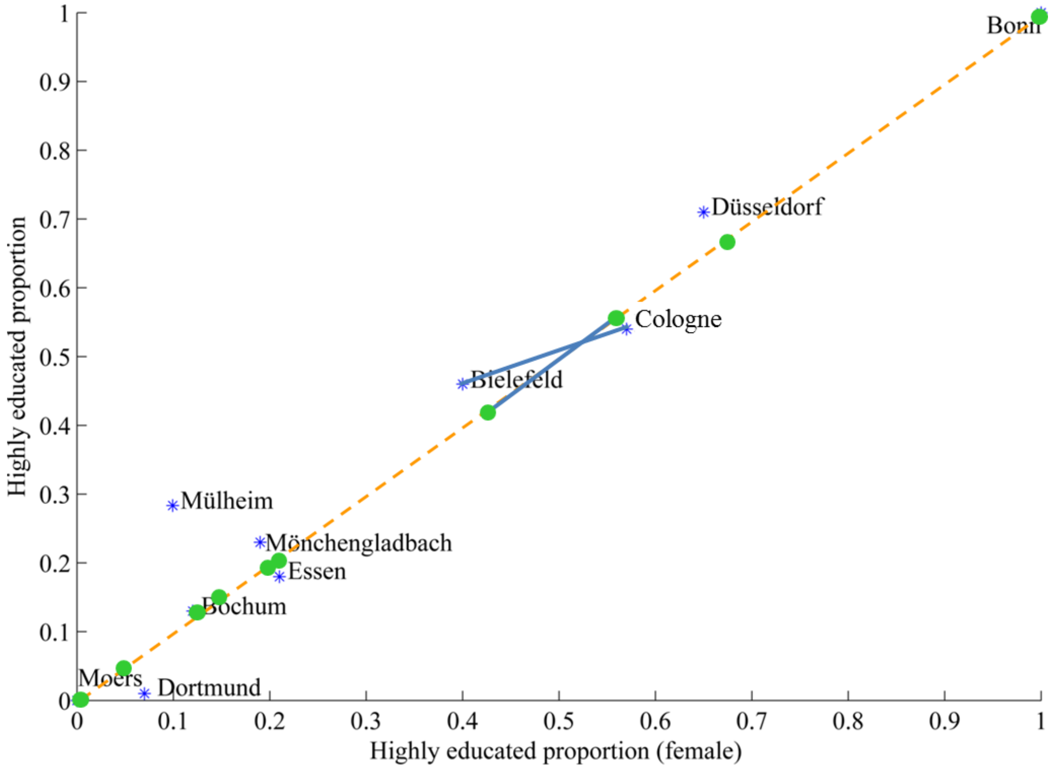

Figure 3: PCA with two education indicators.

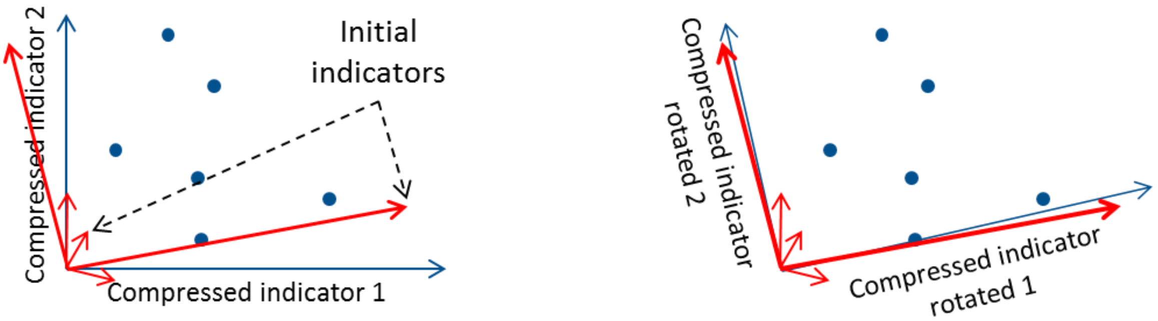

Figure 4: Influence of the initial indicators on the compressed indicators before (left) and after (right) rotation.

Country	# Units	Country	# Units	Country	# Units
Germany	40	Portugal	10	Austria	5
France	36	Switzerland	10	Denmark	5
Italy	32	Greece	9	Finland	5
United Kingdom	31	Hungary	9	Lithuania	3
Poland	28	Sweden	9	Estonia	2
Spain	26	Bulgaria	8	Latvia	2
Turkey	26	Slovakia	8	Malta	2
Netherlands	15	Belgium	7	Slovenia	2
Czech Republic	14	Ireland	6	Cyprus	1
Romania	14	Norway	6	Luxembourg	1

Table 1: Number of Urban Audit cities – units – for each available country.

Category	Indicators
Demographic	Population density in Urban Audit cities
Demographic	Total annual population change over approximately 5 years
Demographic	Total population change over 1 year
Demographic	Total Population at working age
Demographic	Total population in Urban Audit cities
Environmental	Registered cars in Urban Audit cities as number of cars per 1,000 inhabitants
Environmental	Share of journeys to work by car in Urban Audit cities as %
Environmental	Total land area (km^2) according to cadastral register
Environmental	Proportion of solid waste arising within the boundary processed by landfill
Environmental	Collected solid waste in Urban Audit cities as tonnes per inhabitant and year
Environmental	Consumption of water (as cubic metres per annum) per inhabitant
Environmental	Number of days particulate matter concentrations exceeds 50 $\mu g/m^3$ in Urban Audit cities as days per year
Environmental	Number of days ozone concentration exceeds 120 $\mu g/m^3$ in Urban Audit cities as days per year
Human	Number of deaths in road accidents per 10,000 population
Human	Proportion of working age population qualified at level 5 or 6 ISCED – female
Human	Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) living in Urban Audit cities as %
Human	Proportion of working age population at level 1 or 2 ISCED – female
Human	Proportion of working age population qualified at level 1 or 2 ISCED
Human	Proportion of female students in higher education (ISCED level 5-6)
Human	Proportion in part-time employment
Human	Employment/Population (of working age) ratio
Human	Self-employment rate
Human	Unemployment rate in Urban Audit cities as %
Manufactured	Number of stops of public transport per km^2
Social	Cost of a monthly ticket for public transport (for 5-10 km)
Social	Average time of journey to work
Social	Children 0-2 in day care (public and private) per 1,000 children
Social	Number of domestic burglary per 1,000 population
Social	Car thefts in Urban Audit cities as number per 1,000 inhabitants
Social	Available hospital beds in Urban Audit cities per 1,000 inhabitants
Social	Average living area in Urban Audit cities as m^2 per person
Social	Proportion of households living in owned dwellings in Urban Audit cities as %
Social	Price of a m^3 of domestic water
Social	Percentage of households receiving less than half of the national average household income
Social	Proportion of households with children aged 0-17 in Urban Audit cities as %
Social	Average household size in Urban Audit cities as number of persons per household
Social	Proportion of one-person households in Urban Audit cities as %
Social	Nationals born abroad as a proportion of total population
Social	Non-EU nationals as a proportion of total population
Social	EU nationals as a proportion of total population
Social	Nationals as a proportion of total population
Social	Number of tourist overnight stays in registered accommodation per year per resident population
Social	Tourist overnight stays in registered accommodation in Urban Audit cities as number of nights per year
Social	Annual visitors to museums per resident
Social	Cinema seats in Urban Audit cities as seats per 1,000 inhabitants
Social	Percentage of elected city representatives who are men

Table 2: Urban Audit Key Indicators arranged by general categories.

Country	Time frame	# Units	# Indicators	Country	Time frame	# Units	# Indicators
CR	1989-1993	5	19	Netherlands	2007-2009	15	14
CR	1994-1998	5	18	Poland	1989-1993	23	10
CR	1999-2002	5	31	Poland	1994-1998	23	10
CR	2003-2006	4	20	Poland	1999-2002	22	37
CR	2007-2009	14	17	Poland	2003-2006	27	21
France	1989-1993	35	11	Poland	2007-2009	28	24
France	1999-2002	28	24	Romania	1989-1993	14	13
France	2003-2006	34	28	Romania	1994-1998	14	5
Germany	1989-1993	30	15	Romania	1999-2002	13	23
Germany	1994-1998	31	23	Romania	2003-2006	14	14
Germany	1999-2002	38	26	Romania	2007-2009	14	11
Germany	2003-2006	40	34	Spain	1989-1993	16	11
Germany	2007-2009	39	32	Spain	1994-1998	17	13
Italy	1989-1993	27	17	Spain	1999-2002	14	23
Italy	1994-1998	27	11	Spain	2003-2006	25	28
Italy	1999-2002	27	32	Spain	2007-2009	25	28
Italy	2003-2006	32	20	Turkey	1999-2002	26	12
Italy	2007-2009	32	19	Turkey	2003-2006	22	6
Netherlands	1994-1998	10	5	UK	1999-2002	25	11
Netherlands	1999-2002	10	25	UK	2003-2006	31	10
Netherlands	2003-2006	15	30	UK	2007-2009	31	9

Table 3: Remaining data after selection by number of cities – units – and indicators.

		Accuracy limits						Results
Category	Indicators	70 30	70 40	80 30	80 40	90 30	90 40	
Manufactured	Number of stops of public transport per km²	0.67	0.67	1.00	1.00	1.00	1.00	0.89
Environmental	Proportion of solid waste arising within the boundary processed by landfill	0.75	0.38	1.00	0.75	1.00	1.00	0.81
Environmental	Number of days ozone concentration exceeds 120 µg/m³ in Urban Audit cities as days per year	0.83	0.67	0.83	0.83	0.83	0.83	0.81
Social	Nationals born abroad as a proportion of total population	0.81	0.63	0.93	0.57	1.00	0.71	0.78
Demographic	Total population change over 1 year	0.78	0.47	0.93	0.67	0.93	0.77	0.76
Human	Proportion of working age population qualified at level 5 or 6 ISCED – female	0.67	0.44	1.00	0.63	1.00	0.75	0.75
Demographic	Total annual population change over approximately 5 years	0.69	0.45	0.93	0.63	0.93	0.78	0.73
Social	Number of domestic burglary per 1,000 population	0.69	0.46	0.77	0.69	0.85	0.85	0.72
Social	Car thefts in Urban Audit cities as number per 1,000 inhabitants	0.68	0.47	0.79	0.68	0.89	0.74	0.71
Demographic	Total population in Urban Audit cities	0.76	0.34	0.90	0.49	0.95	0.77	0.70
Human	Number of deaths in road accidents per 10,000 population	0.41	0.41	0.81	0.63	1.00	0.94	0.70
Demographic	Total Population at working age	0.74	0.36	0.89	0.49	0.92	0.76	0.69
Human	Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) living in Urban Audit cities as %	0.78	0.22	1.00	0.50	1.00	0.63	0.69
Human	Unemployment rate in Urban Audit cities as %	0.88	0.48	0.88	0.50	0.83	0.50	0.68
Environmental	Number of days particulate matter concentrations exceeds 50 µg/m³ in Urban Audit cities as days per year	1.00	0.25	1.00	0.25	1.00	0.50	0.67
Human	Employment/Population (of working age) ratio	0.71	0.48	0.75	0.60	0.85	0.55	0.66
Social	Cinema seats in Urban Audit cities as seats per 1,000 inhabitants	0.58	0.42	0.82	0.45	1.00	0.64	0.65
Social	Proportion of households living in owned dwellings in Urban Audit cities as %	0.62	0.29	0.89	0.53	0.89	0.63	0.64
Social	Nationals as a proportion of total population	0.70	0.33	0.76	0.52	0.84	0.68	0.64
Social	Percentage of elected city representatives who are men	0.67	0.11	0.89	0.44	1.00	0.67	0.63
Social	Non-EU nationals as a proportion of total population	0.74	0.30	0.76	0.43	0.81	0.67	0.62
Social	Average living area in Urban Audit cities as m² per person	0.76	0.38	0.80	0.40	0.80	0.55	0.62
Environmental	Total land area (km²) according to cadastral register	0.64	0.24	0.83	0.42	0.88	0.67	0.61
Environmental	Consumption of water (as cubic metres per annum) per inhabitant	0.63	0.31	0.73	0.53	0.87	0.60	0.61
Social	Cost of a monthly ticket for public transport (for 5-10 km)	0.71	0.29	0.83	0.33	0.83	0.67	0.61
Human	Proportion of working age population at level 1 or 2 ISCED – female	0.50	0.25	0.86	0.43	1.00	0.57	0.60
Social	Number of tourist overnight stays in registered accommodation per year per resident population	0.45	0.30	0.75	0.55	0.85	0.70	0.60
Environmental	Collected solid waste in Urban Audit cities as tonnes per inhabitant and year	0.44	0.22	0.67	0.56	0.89	0.67	0.57
Social	Available hospital beds in Urban Audit cities per 1,000 inhabitants	0.56	0.32	0.76	0.32	0.88	0.60	0.57
Social	Proportion of one-person households in Urban Audit cities as %	0.64	0.32	0.70	0.35	0.87	0.57	0.57
Human	Proportion of female students in higher education (ISCED level 5-6)	0.57	0.29	0.69	0.38	0.92	0.54	0.57
Social	Average household size in Urban Audit cities as number of persons per household	0.50	0.25	0.60	0.50	0.80	0.70	0.56
Social	Tourist overnight stays in registered accommodation in Urban Audit cities as number of nights per year	0.70	0.25	0.85	0.35	0.90	0.30	0.56
Human	Self-employment rate	0.58	0.38	0.74	0.35	0.74	0.57	0.56
Environmental	Registered cars in Urban Audit cities as number of cars per 1,000 inhabitants	0.53	0.16	0.78	0.39	0.83	0.61	0.55
Demographic	Population density in Urban Audit cities	0.58	0.35	0.68	0.48	0.72	0.48	0.55
Human	Proportion in part-time employment	0.58	0.21	0.74	0.35	0.78	0.52	0.53
Human	Proportion of working age population qualified at level 1 or 2 ISCED	0.67	0.11	0.75	0.38	0.88	0.38	0.53
Social	Proportion of households with children aged 0-17 in Urban Audit cities as %	0.60	0.20	0.68	0.32	0.79	0.53	0.52
Social	Children 0-2 in day care (public and private) per 1,000 children	0.75	0.38	0.57	0.43	0.57	0.29	0.50
Social	Annual visitors to museums per resident	0.31	0.08	0.58	0.33	0.83	0.58	0.45
Social	Average time of journey to work	0.71	0.14	0.69	0.15	0.77	0.23	0.45
Social	EU nationals as a proportion of total population	0.48	0.17	0.76	0.19	0.71	0.38	0.45
Social	Percentage of the households receiving less than half of the national average household income	0.20	0.20	0.67	0.00	1.00	0.33	0.40
Social	Price of a m³ of domestic water	0.40	0.20	0.50	0.50	0.50	0.25	0.39
Environmental	Share of journeys to work by car in Urban Audit cities as %	0.50	0.08	0.36	0.09	0.73	0.36	0.35

Table 4: Results of the overall analysis: Explanatory power of the initial indicators on urban quality of life differences.

Indicators	1989-1993	1994-1998	1999-2002	2003-2006	2007-2009
Number of stops of public transport per km²	*0.00*	*0.00*	1.00	0.50	0.67
Proportion of solid waste arising within the boundary processed by landfill	*0.00*	*0.00*	0.00	0.67	0.33
Number of days ozone concentration exceeds 120 µg/m³ in Urban Audit cities as days per year	*0.00*	1.00	0.33	1.00	*0.00*
Nationals born abroad as a proportion of total population	*0.00*	*0.00*	0.71	0.75	0.67
Total population change over 1 year	0.33	0.67	0.29	0.50	0.50
Proportion of working age population qualified at level 5 or 6 ISCED – female	*0.00*	*0.00*	0.25	0.75	0.00
Total annual population change over approximately 5 years	*0.00*	0.71	0.14	0.14	0.75
Number of domestic burglary per 1,000 population	*0.00*	*0.00*	0.50	0.50	0.40
Car thefts in Urban Audit cities as number per 1,000 inhabitants	*0.00*	1.00	0.50	0.29	0.60
Total population in Urban Audit cities	0.43	0.43	0.20	0.33	0.38
Number of deaths in road accidents per 10,000 population	*0.00*	*0.00*	0.00	0.38	0.57
Total Population at working age	0.50	0.50	0.11	0.40	0.38
Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) living in Urban Audit cities as %	*0.00*	*0.00*	0.00	0.50	0.00
Unemployment rate in Urban Audit cities as %	0.50	0.33	0.50	0.60	0.00
Number of days particulate matter concentrations exceeds 50 µg/m³ in Urban Audit cities as days per year	*0.00*	1.00	0.00	0.00	*0.00*
Employment/Population (of working age) ratio	0.33	0.67	0.25	0.60	1.00
Cinema seats in Urban Audit cities as seats per 1,000 inhabitants	*0.00*	*0.00*	0.20	0.60	0.50
Proportion of households living in owned dwellings in Urban Audit cities as %	0.80	0.00	0.20	0.00	0.00
Nationals as a proportion of total population	0.40	0.80	0.11	0.00	0.50
Percentage of elected city representatives who are men	*0.00*	*0.00*	0.00	0.20	0.00
Non-EU nationals as a proportion of total population	0.50	1.00	0.11	0.20	0.40
Average living area in Urban Audit cities as m² per person	0.40	0.50	0.29	0.50	0.33
Total land area (km²) according to cadastral register	0.60	0.20	0.00	0.25	0.20
Consumption of water (as cubic metres per annum) per inhabitant	1.00	0.33	0.33	0.20	0.00
Cost of a monthly ticket for public transport (for 5-10 km)	*0.00*	*0.00*	0.00	0.33	0.33
Proportion of working age population at level 1 or 2 ISCED – female	*0.00*	*0.00*	0.25	0.33	0.00
Number of tourist overnight stays in registered accommodation per year per resident population	1.00	0.67	0.00	0.20	0.40
Collected solid waste in Urban Audit cities as tonnes per inhabitant and year	*0.00*	*0.00*	0.00	0.67	0.00
Available hospital beds in Urban Audit cities per 1,000 inhabitants	0.00	0.60	0.00	0.50	0.50
Proportion of one-person households in Urban Audit cities as %	0.29	0.50	0.33	0.25	0.33
Proportion of female students in higher education (ISCED level 5-6)	*0.00*	*0.00*	0.20	0.33	0.33
Average household size in Urban Audit cities as number of persons per household	*0.00*	0.00	0.00	0.50	0.33
Tourist overnight stays in registered accommodation in Urban Audit cities as number of nights per year	1.00	0.33	0.00	0.20	0.40
Self-employment rate	0.40	0.00	0.44	0.43	0.00
Registered cars in Urban Audit cities as number of cars per 1,000 inhabitants	0.50	0.00	0.25	0.20	0.00
Population density in Urban Audit cities	0.60	0.60	0.00	0.25	0.40
Proportion in part-time employment	0.50	0.33	0.00	0.17	0.50
Proportion of working age population qualified at level 1 or 2 ISCED	*0.00*	*0.00*	0.25	0.00	0.00
Proportion of households with children aged 0-17 in Urban Audit cities as %	0.17	0.00	0.13	0.33	0.50
Children 0-2 in day care (public and private) per 1,000 children	*0.00*	*0.00*	0.00	0.67	0.50
Annual visitors to museums per resident	0.00	0.00	0.00	0.00	0.25
Average time of journey to work	0.33	0.00	0.20	0.00	0.00
EU nationals as a proportion of total population	0.67	1.00	0.00	0.00	0.00
Percentage of the households receiving less than half of the national average household income	*0.00*	*0.00*	0.00	0.00	0.50
Price of a m³ of domestic water	*0.00*	*0.00*	0.00	0.25	0.00
Share of journeys to work by car in Urban Audit cities as %	0.50	0.00	0.00	0.00	0.00

Table 5: Results of the time frame analysis: Explanatory power of the initial indicators on urban quality of life differences.

Indicators	Germany	Romania	Netherlands	Italy	Turkey	UK	Spain	France	Poland	CR
Number of stops of public transport per km^2	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Proportion of solid waste arising within the boundary processed by landfill	0.00	0.00	0.00	1.00	1.00	0.00	0.50	0.00	0.00	0.00
Number of days ozone concentration exceeds 120 µg/m^3 in Urban Audit cities as days per year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.00	0.67
Nationals born abroad as a proportion of total population	0.00	0.50	0.67	0.00	1.00	0.00	1.00	1.00	1.00	0.00
Total population change over 1 year	0.00	0.80	0.50	0.40	0.00	1.00	0.67	0.00	0.25	0.20
Proportion of working age population qualified at level 5 or 6 ISCED – female	0.33	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
Total annual population change over approximately 5 years	0.00	0.75	0.50	0.75	0.00	0.50	0.50	0.00	0.25	0.25
Number of domestic burglary per 1,000 population	0.00	0.00	0.00	0.00	0.00	1.00	0.50	0.00	1.00	0.00
Car thefts in Urban Audit cities as number per 1,000 inhabitants	0.00	0.00	0.00	0.00	1.00	1.00	0.50	1.00	0.00	0.33
Total population in Urban Audit cities	0.00	0.80	0.25	0.40	1.00	1.00	0.40	0.00	0.20	0.00
Number of deaths in road accidents per 10,000 population	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00
Total Population at working age	0.00	0.80	0.25	0.40	1.00	1.00	0.40	0.00	0.25	0.00
Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) living in Urban Audit cities as %	0.33	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Unemployment rate in Urban Audit cities as %	0.00	0.50	1.00	0.50	1.00	1.00	0.75	0.50	0.50	0.25
Number of days particulate matter concentrations exceeds 50 µg/m^3 in Urban Audit cities as days per year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Employment/Population (of working age) ratio	0.25	0.50	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.33
Cinema seats in Urban Audit cities as seats per 1,000 inhabitants	0.00	0.50	0.00	0.00	0.00	0.00	0.50	1.00	0.67	0.00
Proportion of households living in owned dwellings in Urban Audit cities as %	0.00	0.00	0.00	0.50	0.00	1.00	0.50	0.33	1.00	0.50
Nationals as a proportion of total population	0.00	0.00	0.25	0.40	1.00	0.00	0.75	0.00	0.00	0.67
Percentage of elected city representatives who are men	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU nationals as a proportion of total population	0.00	0.50	0.33	0.20	1.00	0.00	0.75	0.00	0.00	0.00
Average living area in Urban Audit cities as m^2 per person	0.00	0.75	0.00	0.00	0.00	0.00	0.00	1.00	0.80	0.00
Total land area (km^2) according to cadastral register	0.20	0.00	0.00	0.40	0.00	0.00	0.33	0.00	0.50	0.00
Consumption of water (as cubic metres per annum) per inhabitant	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.40	0.33
Cost of a monthly ticket for public transport (for 5-10 km)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00
Proportion of working age population at level 1 or 2 ISCED – female	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of tourist overnight stays in registered accommodation per year per resident population	0.50	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
Collected solid waste in Urban Audit cities as tonnes per inhabitant and year	0.00	0.00	0.00	0.33	0.00	0.00	0.50	0.00	0.00	0.00
Available hospital beds in Urban Audit cities per 1,000 inhabitants	0.00	0.60	0.00	0.50	0.00	0.00	0.00	0.00	0.40	0.20
Proportion of one-person households in Urban Audit cities as %	0.00	0.50	0.67	1.00	1.00	1.00	0.25	0.00	0.00	0.00
Proportion of female students in higher education (ISCED level 5-6)	0.00	0.00	0.50	0.00	1.00	0.00	0.00	0.00	0.33	0.00
Average household size in Urban Audit cities as number of persons per household	0.33	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Tourist overnight stays in registered accommodation in Urban Audit cities as number of nights per year	0.25	0.67	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.00
Self-employment rate	0.20	0.67	0.00	0.00	1.00	1.00	0.00	0.67	0.00	0.25
Registered cars in Urban Audit cities as number of cars per 1,000 inhabitants	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.00	0.33
Population density in Urban Audit cities	0.00	0.00	0.00	0.80	0.00	0.00	0.67	0.00	0.50	0.20
Proportion in part-time employment	0.00	0.00	0.00	0.00	0.00	0.67	0.25	0.33	0.00	0.25
Proportion of working age population qualified at level 1 or 2 ISCED	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Proportion of households with children aged 0-17 in Urban Audit cities as %	0.40	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.50	0.00
Children 0-2 in day care (public and private) per 1,000 children	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.67	0.00
Annual visitors to museums per resident	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average time of journey to work	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.50
EU nationals as a proportion of total population	0.00	0.50	0.00	0.20	0.00	0.00	0.25	0.33	0.00	0.00
Percentage of the households receiving less than half of the national average household income	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Price of a m^3 of domestic water	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Share of journeys to work by car in Urban Audit cities as %	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00

Table 6: Results of the countries' analysis: Explanatory power of the initial indicators on urban quality of life differences.

Category	Indicators
Demographic	Population density
Demographic	Total population
Demographic	Total Population at working age
Demographic	Total population change over 1 year
Environmental	Collected solid waste as tonnes per inhabitant and year
Environmental	Consumption of water (as cubic metres per annum) per inhabitant
Environmental	Proportion of solid waste arising within the boundary processed by landfill
Environmental	Registered cars as number of cars per 1,000 inhabitants
Environmental	Share of journeys to work by car as %
Environmental	Total land area (km^2) according to cadastral register
Human	Employment/Population (of working age) ratio
Human	Proportion in part-time employment
Human	Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) as %
Human	Proportion of working age population at level 1 or 2 ISCED – female
Human	Proportion of working age population qualified at level 1 or 2 ISCED
Human	Proportion of working age population qualified at level 5 or 6 ISCED – female
Human	Unemployment rate as %
Manufactured	Number of stops of public transport per km^2
Social	Available hospital beds per 1,000 inhabitants
Social	Number of tourist overnight stays in registered accommodation per year per resident population
Social	Tourist overnight stays in registered accommodation as number of nights per year

Table 7: Available indicators for all levels – cities, regions, countries.

Indicators	Cities – 21 Indicators as Input	Cities – 46 Indicators as Input
Number of stops of public transport per km²	X	X
Proportion of solid waste arising within the boundary processed by landfill	X	X
Unemployment rate in Urban Audit cities as %	X	X
Total population in Urban Audit cities	X	X
Total population change over 1 year	X	X
Proportion of working age population at level 1 or 2 ISCED – female	X	
Proportion of working age population qualified at level 1 or 2 ISCED	X	
Total Population at working age		X
Proportion of working age population qualified at level 5 or 6 ISCED – female		X
Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) as %		
Total land area (km²) according to cadastral register		
Collected solid waste in Urban Audit cities as tonnes per inhabitant and year		
Tourist overnight stays in registered accommodation as number of nights per year		
Registered cars in Urban Audit cities as number of cars per 1,000 inhabitants		
Employment/Population (of working age) ratio		
Consumption of water (as cubic metres per annum) per inhabitant		
Number of tourist overnight stays in registered accommodation per year per resident population		
Available hospital beds in Urban Audit cities per 1,000 inhabitants		
Proportion in part-time employment		
Population density in Urban Audit cities		
Share of journeys to work by car in Urban Audit cities as %		

Table 8: Urban comparison by different input sizes.

Indicators	Countries – 21 Indicators as Input	Countries – 36 Indicators as Input
Total Population at working age	X	X
Total population	X	X
Population density	X	X
Tourist overnight stays in registered accommodation as number of nights per year	X	X
Number of stops of public transport per km²	X	X
Proportion in part-time employment	X	
Available hospital beds cities per 1,000 inhabitants	X	
Proportion of working age population at level 1 or 2 ISCED – female		X
Proportion of working age population qualified at level 5 or 6 ISCED – female		X
Proportion of working age population qualified at level 1 or 2 ISCED		
Employment/Population (of working age) ratio		
Total land area (km²) according to cadastral register		
Unemployment rate as %		
Number of tourist overnight stays in registered accommodation per year per resident population		
Total population change over 1 year		
Registered cars as number of cars per 1,000 inhabitants		
Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) as %		
Collected solid waste as tonnes per inhabitant and year		
Total annual population change over approximately 5 years		
Share of journeys to work by car as %		
Proportion of solid waste arising within the boundary processed by landfill		

Table 9: Country comparison by different input sizes.

Indicators	Cities	Regions	Countries
Total population	X	X	X
Proportion of working age population at level 1 or 2 ISCED – female	X	X	
Number of stops of public transport per km²	X		X
Total population change over 1 year	X		
Proportion of working age population qualified at level 1 or 2 ISCED	X		
Unemployment rate as %	X		
Proportion of solid waste arising within the boundary processed by landfill	X		
Total Population at working age		X	X
Tourist overnight stays in registered accommodation as number of nights per year		X	X
Total land area (km²) according to cadastral register		X	
Consumption of water (as cubic metres per annum) per inhabitant		X	
Number of tourist overnight stays in registered accommodation per year per resident population		X	
Proportion in part-time employment			X
Population density			X
Available hospital beds per 1,000 inhabitants			X
Proportion of working age population qualified at level 5 or 6 ISCED – female			
Proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) as %			
Collected solid waste as tonnes per inhabitant and year			
Registered cars as number of cars per 1,000 inhabitants			
Employment/Population (of working age) ratio			
Share of journeys to work by car as %			

Table 10: Comparison of the importance of 21 indicators for different levels.