SEEDS
Sustainability Environmental Economics and Dynamics Studies

Working Paper Series

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13/2015

SEEDS Working Paper 13/2015
July 2015
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Smart and sustainable cities in the European Union. An ex ante assessment of environmental, social, and cultural domains*

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Abstract

The aim of the paper is to define a set of smartness and sustainability indicators applicable to European cities and to assess their outcome in an *ex-ante* perspective with regard to the implementation of Europe 2020 strategy. Following the DPSIR (Driving forces, Pressures, State, Impact, Response) model we select a bundle of indicators for three relevant sustainability domains (environmental, social, cultural), which are proper of the smart city definition. Then we define groups of homogeneous cities for each domain by using a two-step cluster analysis. Results show the existence of heterogeneous groups of cities that are likely to become smart in the cultural domain, side by side to groups of more developed urban areas that have acquired a substantial advantage in the environmental and social dimensions.

Keywords: smartness, sustainability, urban areas, Europe 2020, DPSIR model

JEL: Q01; R29

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* We thank Anna Montini for the help and support during the preparation of the paper. We are also grateful to the participants at the 53rd ERSA Congress held in Palermo on 27th–31th August 2013 and to Marco Modica for useful comments and suggestions. Usual disclaimers apply.

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1. Introduction

Cities are crucial actors in shaping economic systems, being engines of economic growth. At the same time they are also “the location of some major problems and future challenges” (Dodgson and Gann, 2011, p. 109) arising in presence of any change dealing with the interaction among institutional, technological and human systems. Not surprisingly, cities have become an autonomous field of policy intervention in order to address the present global crisis. Within this context, the notion of urban smartness, associated with a “model of a technologically advanced, green and economically attractive city” (Vanolo, 2014, p. 889), has recently attracted much attention from both policy-makers and academics. On the one side, this theoretical and institutional debate on the smart city concept has grown considerably and currently raises the need of diversifying the debate and going beyond the mere criticism on the dominance of IT vendors in urban smart city strategy. On the other side, the intrinsic multi-dimensionality of smartness and sustainability, couples with cities’ complexity, thus calling for specific assessments able to distinguish between different types of urban areas.

The European Union has developed a renewed effort in order to support a sustainable urban development. New measures have been put in place in order to promote urban sustainability by leveraging on industry-led urban technology applications in different sectors: energy, transport, education and ICT. Such effort falls within that broader policy aimed at smartening up European urban areas while acknowledging cities’ pivotal role in the achievement of the objectives of Europe 2020 Strategy. Sustainability principle interacts with all different dimensions attached to the smart city concept either implicitly or explicitly, and can thus be considered as a cross-conceptual criterion that allows a comprehensive assessment of smart city strategies in accordance with the framework of Europe 2020 agenda.

According to these premises, our paper aims at defining a set of indicators applicable to European cities in order to jointly assess their degree of smartness and sustainability. For each of the dimensions taken into account (social, environmental and cultural) we build up a system of indicators which can allow a thorough comparison among urban systems following the DPSIR (Driving Force, Pressure, State, Impact, Response) model, which has been developed by the European Commission to address sustainability issues.

Then we look for homogeneous groups of cities through a multivariate technique (two-step cluster analysis) and identify their strengths and weaknesses in terms of structural elements, economic dynamics and policy answers. Eventually, we draw an original picture of European cities before the implementation of smart city initiatives under Europe 2020 strategy. Since such initiatives are deemed to be holistic and usually reflect the actual situation of the involved cities, our study is a supporting tool for understanding the specificities of European cities at the outset of this policy in a multidimensional framework. Urban development is a complex process involving different dimensions that cannot rely on a unique ranking, provided that the direction of related policies should also refer to local actors, their preferences, and their individual objectives. Bringing to the debate quantifiable tools through the selection of proper indicators could contribute to design sound "smart city" policies in each urban region.

Accordingly, this study contributes to determine a multidimensional baseline of European cities in accordance with the objectives of Europe 2020 strategy, drawing a picture of the conditions of European cities before the kick-off of the Smart Cities and Communities initiative. By merging together the information coming from several indicators, we provide a comprehensive *ex ante* appraisal of European urban areas in a comparative perspective. Obviously there is the risk to mix chalk and cheese in building this set of indicators. Measuring is an act of simplification that entails the risk of putting together heterogeneous features. However, it is still extremely useful to compare cities and identify best practices. In the light of the smart city concept, the construction of multidimensional indicators is the preliminary step for any activity of comparison of the ongoing initiatives, while taking into account the latent differentiation of the underlying objectives arising from cities' heterogeneity.

The paper is structured as follows. Section 2 briefly reviews the relationship between the smart city concept and the sustainability principle. Section 3 synthesises of the Europe 2020 strategy for urban areas. Section 4 summarizes the main characteristics of the DPSIR model. Section 5 selects the relevant indicators. Section 6 displays the methodology. Section 7 shows the results. Section 8 concludes.

2 The concept of smart city in a sustainability perspective

Smart city has nowadays become a widespread and popular label. Its broad application area has led to the development of a heterogeneous set of definitions and experiences. As a consequence there is a concrete risk of fuzziness, vagueness and ambiguity when using this concept. However, the concept is not radically new. The first definition of smart city has been provided by Hall in 2000. It emphasizes the image of a city "that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens" (Hall, 2000, p. 634). This definition, centered on physical infrastructures, then evolved under the influence of other previous concepts centered on ICT technology: wired city, technocity, digital city, creative city and knowledge-based city. Given the emphasis on the opportunities offered by ICT, it is not surprising that one of the first meanings of smart city emphasizes the role of digital information for ensuring citizens a better quality of life (Ratti and Berry, 2007) through the incorporation of digital information into new products and/or their use in specific areas of intervention. Similarly, three out of the four meanings of intelligent cities (Komninos, 2008), which is the closest one to smart city, are related to the application and innovative use of information technology. In this perspective the smart city is mainly a new opportunity related to investments in ICT services and infrastructure. The use of ICT provides agents with economic and institutional attributes of intelligence, connectivity and efficiency that characterize it (Washburn and Sindhu, 2010). This definition emphasizes the role of technology in addressing the potential contribution of urban areas to economic growth, environmental sustainability, and effectiveness of public services. In turn this contribution depends on the extent to which ICT technologies integrate the different types of urban infrastructure within a unique complex system of systems.

However, this techno-centred approach to "smartness", which implicitly assumes the preponderant role of technology/IT investments in solving urban problems, has been increasingly criticized both in the scholarly and policy realm. Indeed, the role of technological innovation and change through ICT is only one aspect of the notion of "smartness". Technological innovation does not solve any issue in itself. Rather, it put smart cities at the centre of a bundle of “modern dilemmas” dealing with “sustainability, wealth creation and distribution, infrastructure investment, poverty and exclusion reduction, work as well as play” (Marceau, 2008, p. 145). Accordingly, a smart city “involves quite a diverse range of things – information technology, business innovation, governance, communities and sustainability” and, even more important, “the label itself often makes certain assumptions about the relationship among these things” (Hollands, 2008, p. 306). Actually, a review of the definitions proposed by the literature show other recurring characters (Caragliu et al., 2011; Tranos and Gertner, 2012):

i. The pursuit of social and environmental sustainability as a strategic goal of smart cities;
ii. the role of network infrastructures;
iii. the recognition of entrepreneurship as an essential, but not unique, driver, of urban development;
iv. the objective of maximizing the residents' access to public utilities, in order to promote social inclusion;
v. the crucial role of creative industries;
vi. the identification of social and relational capital as triggering factors of smart city projects.

Moving from these insights Caragliu and Del Bo (2012, p. 100) qualify a city as smart “when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance”. Other related definitions focus on the human capital basis of the smart city concept (Lombardi et al., 2009), on the social implication of the widened access to public information and services (Anthopulos and Fitsilis, 2010), and on the new ways of interaction between the public domains with cities’ stakeholders (Nam and Pardo, 2010). The most popular definition of the smart city concept in Europe, however, is the one elaborated by Giffinger et al. (2007). Here, smart cities are defined through the concurrent combination of single aspects that ranges from innovation to education and quality of life (smart economy, smart mobility, smart environment, smart people, smart living and smart governance), each of them differing from time to time. In a planning phase, smart city is also a normative concept embracing different dimensions that embody a plurality of criteria for all the participating actors.

The distinguishing feature of the concept is therefore to combine together different visions of urban life in an integrated way. However, the wide spectrum of objectives, themes and sectors involved in smart city definitions leads to a fragmentation of the concept when projects are actually put into practice. Several trade-off arises from the intrinsic nature of the challenge faced by European cities, i.e. "combining competitiveness and sustainable urban development simultaneously" (Giffinger et al., 2007, p. 5). In order to deal with the pursuit of such heterogeneous objectives the smart city has thus been conceived as a "framework for policies supporting technological and ecological urban transition…and fertilising national and local political agendas" (Vanolo, 2014, p. 894) deriving from the assemblage of several pre-existing urban issues. Meanwhile, an original and complex set of indicators is needed for providing additional evidence able to capture the multidimensionality of urban environment.

According to this wave of issues and definitions, sustainability and liveability are often acknowledged as the main final objectives of the smart city strategies (Toppeta, 2010). By connecting the different types of both tangible and intangible infrastructures (the IT infrastructure, the social infrastructure, and the business infrastructure) through proper governance mechanisms, urban areas may leverage the collective intelligence of the system and substantially contribute to social, technological, and environmental development (Harrison et al., 2010). In this perspective, sustainability would thus act as a transversal principle and not just as a cliché-like combination of economic-social-environmental spheres. Moreover, sustainability can be seen as a cross conceptual criterion to analyse the outcome of smart-oriented urban policies. It joins together different aspects and issues of urban life, while it is related to other smart city dimensions via the objective of quality of life (Polese and Stern, 2000; Inoguchi et al., 1999; Satterthwaite, 1999) or liveability. In turn, the nexus between liveability and sustainability imposes a constraint on smart cities projects ensuring that the improvement in the quality of life is positively correlated with urban environmental quality. Indeed, one of the main challenges of smart cities is "to enable both urban liveability and environmental sustainability" (Newton, 2012, p. 88).

Following this line of reasoning, the analysis of the mechanisms of production of smart and sustainable urban conduct can be grouped in three broad and heterogeneous dimensions: environmental, social, cultural. Environmental dimension primarily deals with the effects (including externalities) of urban activities on natural resources, pollution, health conditions, all of which are complex and inter-related. Social sustainability promotes inclusiveness in urban initiatives related to the deployment and the use of ICT. In a smart city, different communities living in urban areas can take advantage of new opportunities offered by the integration of different social groups, thus promoting the interaction between creativity and technological innovation (Cohendet and Simon, 2008). Moreover, smartness grounds on creativity (Florida, 2002), human and social capital (Caragliu and Del Bo, 2012), and amenities (Gottlieb and Glaeser, 2006; Shapiro, 2006). These “soft" factors, which are partially overlapping, positively contribute to make urban areas more competitive and attractive. Nevertheless, they are also compatible with the definitions proposed by Giffinger et al. (2007) and Harrison et al. (2010). All together, they can be clustered under the cultural domain (Hawkes, 2001[4]) which includes cultural diversity, arts, entertainment, tourism, innovative services, entrepreneurship, open atmosphere, and the access to social capital and networks (Nijkamp and Kourtit, 2013). Overall, the cultural dimension supports the creation of new development opportunities for the whole urban community, taking into account the existence of a multiplicity of stakeholders. In this way we build up three policy-useful “pillars” based on both hard and soft indicators, whose relative weight is comparable across the three dimensions. However, each dimension is still too heterogeneous and general for being the object of a correlation-based analysis. In order to address this issue in the empirical analysis, each of the three dimensions will be divided into five subcategories in accordance with the DPSIR model.

<Table 1>

[4] Hawkes argues that the pillars of sustainability are actually four, instead of the traditional three (environmental, social, economic): cultural vitality, social equity, environmental responsibility, economic viability.

3. Smart cities and sustainability principle in Europe 2020 strategy

European cities are places of social progress and environmental regeneration, as well as places of attraction and engines of economic growth. They create almost 80% of the EU's gross domestic product with their concentration of trade, business and skills, while the proportion of Europeans living in urban areas is expected to grow to 85% by 2050. On the other hand, cities are seen as unrivalled providers of "the basic ingredients for quality of life in all its senses: environmental, cultural and social" and are thus called to reconcile "economic activities and growth with cultural, social and environmental consideration" (European Commission, 2010b, p. 42-43) in line with a holistic model of sustainable city development.

Indeed, since 2006 the European Commission has been acknowledging the role of urban areas in delivering the objectives of the EU Sustainable Development Strategy: "the environmental challenges facing cities have significant consequences for human health, quality of life of urban citizens and the economic performance of the cities themselves" (European Commission, 2006). This recognition follows the 6th Environment Action Programme (6th EAP) which called for the development of a Thematic Strategy on the Urban Environment for contributing "to a better quality of life through an integrated approach concentrating on urban areas [and] to a high level of quality of life and social well-being for citizens by providing an environment where the level of pollution does not give rise to harmful effects on human health and the environment and by encouraging sustainable urban development" (European Parliament and European Council, 2003). However, cities have to cope with negative effects of urbanization and international division of labour. Many environmental and social problems are concentrated in the cities. European urban areas consume 70% of energy, which accounts for 75% of the EU's total greenhouse gas emissions (GHG), while congestion costs in Europe accounts for about 1% of GDP every year, most of which arising from urban areas (European Commission, 2012).

These issues call for the elaboration of suitable sustainable development patterns for urban areas. In this respect, the European policy is committed to creating a high quality urban environment that contributes to making Europe a more attractive place to work and invest and eventually to achieving the conditions for a urban sustainable development. Better urban management can reduce the impacts of the day to day use of resources: “avoiding urban sprawl through high density and mixed-use settlement patterns offers environmental advantages regarding land use, transport and heating contributing to less resource use per capita” (European Environmental Agency, 2006). As a consequence, sustainability goals must be taken into account in the evaluation of smart city projects that are flourishing throughout the continent. Eventually, in 2012 the European Commission launched “The Smart Cities & Communities (SCC) Initiative” in order “to make Europe's cities more efficient and more sustainable in the area of energy, transport and information and communication technologies” (European Commission, 2012). The Communication of 10th July 2012 embodies the SCC initiative into the Europe 2020 strategy whose first objective is to promote a “smart, inclusive and sustainable growth in Europe and to provide a framework for the EU to emerge strengthened from the current financial and economic crisis” (European Commission, 2012, p. 2).

The SCC initiative requires European cities to become the forerunners of Europe 2020 strategy. Specifically, it calls for European cities as “places of advanced social progress and environmental regeneration, as well as places of attraction and engines of economic growth based on a holistic integrated approach in which all aspects of sustainability are taken into account” (European Commission, 2012, p. 3). To achieve this purpose, European policy-makers suggest differentiating projects and interventions according to the heterogeneous strengths and weaknesses of each single urban area. Before approving every kind of technology-based project, cities should find a balance among conflicting and sometimes contradictory objectives, while moving towards holistic models of sustainable development. This objective entails a major challenge for the EU: designing and adapting cities into smart, efficient and sustainable places able to offer both a high quality of life to present-day citizens and benefits for future generations. The importance of technology is not in the technology itself, but relies on the opportunities that technology makes available to improve the ways cities meet the changing needs and preferences of their residents. ICT-based solutions are thus seen as a tool to address public issues on the basis of a multi-stakeholder, municipality based partnership (European Parliament, 2014).

The complex mix of challenges faced by European cities requires building up an approach able to guarantee sustainable urban development through investments in infrastructure (transport, housing, centers of learning, cultural facilities), and policy measures supporting socio-economic development and inclusion. Since all cities have potential but in different ways, smart city policies should be tailored to these contexts. This need of differentiation is increasingly recognized in policy spheres and underlies the place-based debate around the new EU cohesion policy. However this debate has not affected the reality of smart city policies yet. In order to deal with this drawback, we suggest that a preliminary step in order to put European cities at the centre of the policy effort to promote a smart, sustainable, and inclusive growth is the elaboration of appropriate indicators that take into account the different characteristics of the smart city concept as it has been applied in the European Union[5]. In this way researchers and local administrators could identify the appropriate measures for each specific situation and, at the same time, take full advantage from the exchange of information throughout the European Union. Such indicators should be initially used for building a baseline measurement system suitable to implement an *ex ante* evaluation process. This would help local authorities to conceive their city as a unique sustainable urban system already from the outset of the smart city initiatives, and to acknowledge the close inter-relation among competitiveness, division of labour, inequality, environment, and attractiveness.

4. The DPSIR model

The existence of a new heterogeneous bundle of aspects covered by the same attribute has raised the need for suitable inter-related indicators to measure cities' smartness, leading to the development of a great variety of multidimensional rankings. Our proposal is to align smartness characteristics with Europe 2020 targets, most notably sustainability, by building a set of indicators based on the DPSIR model (acronym for: Driving Force, Pressures, State, Impact, Response), which has been developed by the European Agency for the Environment grounding on the previous model "Pressures, State, Answers" (PSA), developed by the OECD (1998, 1999, 2002).

The model relates the state of the environment in function of the driving forces that determined pressure on the environment. At the same time the DPSIR model entails a policy intervention as it provides indicators on the actions (responses) undertaken by the

[5] It is worth to notice that two-third of the smart cities mapped by the European Parliament (2014) address more than one characteristic and that the overall average of involved characteristics is 2.5.

policy maker, thus allowing to check whether the policy intervention has produced the desired effects.

The five families of indicators are divided as follows:

i. D (*Driving Force):* underlying factors influencing a variety of different variables;
ii. P (*Pressure):* indicators referring to the variables that cause environmental problems;
iii. S (*State):* indicators showing the present condition of the environment;
iv. I (*Impact):* indicators describing the ultimate effects of changes of state;
v. R (*Response):* indicators demonstrating the efforts of society (i.e. decision-makers) to solve the problems.

The main properties and functions of each family of indicators in the DPSIR framework are the following ones:

i. *Driving Force* indicators usually are not *responsive ("elastic")*. The monitored phenomena are driven by powerful economic and demographic forces, and therefore it can hardly be expected that these trends will change in future. However, these indicators are useful to calculate a variety of pressure indicators, to help decision-makers, and to plan the actions ("responses") needed to avoid future problems and shape the scenario for a long-term planning.
ii. *Pressure* indicators point directly at the causes of problems. One specific feature of pressure indicators is that they should be *responsive*, that is, a decision-maker has indeed a chance to affect the indicator (and thus the problem) by launching appropriate actions. They also serve as an incentive for rational answers, since they may validate the *effectiveness* of the political action early enough to hold the decision-maker responsible.
iii. *State* indicators mainly serve to make an *ex ante* assessment of the situation. In contrast, as their changes are slow, they are suitable for evaluating the policy intervention only in the long run.
iv. *Impact* indicators react even slower than state indicators. Their main purpose is to make evident the DPSIR patterns, in particular *cause-effect chains*, and to facilitate informed discussions about actions to avoid negative impacts in future.

v. *Response* indicators are very fast, since they monitor the *measures* which are intended to make the slow socio-economic system move. There is no *a priori* guarantee, however, that political responses will be effective; the monitoring of their *success* can be performed only through pressure and state indicators.

DPSIR model fits well to our perspective because it allows a selection of an inter-related multidimensional set of indicators that are combined together into the three chosen dimensions that in their turn represent a possible application of the “smart and sustainable” binomial. Through the DPSIR model we can achieve a flexible integration among these economic, social and cultural indicators, while taking account the evidence that previous researches on European cities show consistent evidence of a positive association among smartness indicators such as urban wealth, the presence of creative professionals, the quality of urban transportation network, ICT diffusion, and human capital (Caragliu et al., 2011).

5. Dataset and indicators

Our empirical study grounds on the European Urban Audit dataset which is “a set of reliable and comparative information on the quality of life in selected urban areas in Europe” (Eurostat, 2010, p. 203). It includes 323 cities in 27 Member States, plus 47 cities from Switzerland, Norway, Croatia and Turkey, relying on more than 300 indicators dealing with different aspects of urban life, e.g. demography, housing, health, crime, labour market, income disparity, local administration, educational qualifications, environment, climate, travel patterns, information society, cultural infrastructure. Although the actual coverage of the survey is still partial and asymmetric, Urban Audit represents one of the most important sources for applied studies on the smartness of European urban regions (Caragliu et al., 2011; Caragliu and Del Bo, 2012; Kourtit et al., 2012)[6].

[6] Caragliu et al. (2011) provide 6 indicators of smartness: GDP per capita; number of employed persons in cultural and entertainment industry, multimodal accessibility and length of the network of public transport, e-government, human capital. Caragliu and Del Bo (2012) focus on three aspects: culture (proxied by the number of visitors to museums per resident), mobility (proxied by the length of public transportation), and e-government (proxied by the number of administrative forms available for download from official web site). Kourtit et al. (2012) analyze cities’ environmental sustainability using data on the employment structure of the urban workforce, on the degree of business and socio-cultural attractiveness, on the presence of public facilities and of sophisticated e-services. Using Urban Audit data for years 2007-2009, we select the indicators according to the different steps of the DPSIR model and to the sustainability dimension they are attached with.

For the environmental dimension we take into account those indicators that refer to mobility and natural resources: public transport network, air pollution and natural resources consumption. Driving Force indicators deal with demographic and mobility. Pressure indicators are related to the consumption of natural resources, notably water and waste. State is measured by air pollution and landfilled waste. Impact indicators concern the negative effects of mobility inefficiencies and pollution. These effects are proxied by health damages caused by respiratory diseases and car accidents. Finally, Response indicators deal with a wide variety of "green" public services": local transport, parking availability, green areas, and waste recycling.

Social dimension is one of the most critical issues attached to the smart city concept. Smart cities have to address the risk of exacerbating inequality further to ICT-based projects (Graham, 2002). Although smart cities are expected to favour everyone's access to information technology, this does not avoid the risk of creating a "two speed" city. Namely, cities facing economic decline have growing difficulties in facilitating socio-economic insertion due to the lack of jobs and the reduction of public budget. Smart cities are requested to mitigate this risk by strengthening urban social infrastructure, which is viewed as an indispensable endowment of sustainable urban systems. In this perspective, following Hollands (2008), we consider indicators related to wealth, education, employment, activity rate, security, business crisis and migration. All these indicators regard social sustainability as they affect the sense of wellbeing and provide confidence in the future. Driving Force indicators deal with demographic and social variables, and affect both wealth and employment. Pressure indicators deal with the change in Driving Forces indicators, together with indicators related to people's capability to satisfy their basic needs (Atkinson, 2002), such as housing. A part of them are also related to the cultural dimension to the extent to which they measure cultural diversity. In particular, the presence of immigrants is a source of both ethnicity and language based diversity which in turn is positively associated with amenities and higher productivity (Alesina and Ferrara, 2004), but negatively associated with public goods provision (Glaeser and Alesina, 2005). State indicators deal with direct measures of employment, poverty, housing needs. Impact indicators deal with urban crime indicators, the only available figure that represents a widely recognized effect of poverty and social exclusion. Finally, Response indicators concern policy answer in terms of childcare, health services and education.

Cultural dimension deals with vitality, participation and attractiveness of an area. When applying this definition to urban areas we immediately think to human capital externalities (Glaeser and Maré, 2001; Moretti, 2004; Glaeser et al., 2010) and to the concept of creative city (Florida, 2005) joined with technological innovation. Human capital externalities are generated by the concentration of skills in the city, which is again proxied by the concentration of graduates. This concentration attracts other skilled workers thanks to higher productivity (and wage premium) attached to knowledge intensive industries located in urban areas and other local knowledge spillovers, thus becoming an attractive and retaining factor for educated and skilled households. Notably, the city serves as an ideal pool of human capital accumulation and a hotspot of complementarities between human capital and knowledge-sensitive capital. Creativity is attached to new ways of thinking and acting and ensures that the urban area is attractive for high-skilled workforce. It is rooted on technology, tolerance, and talent ("the three Ts"). Technology in a smart city perspective is directly related to ICT investment and, more generally, to the access to knowledge and information. Tolerance deals with the openness to socio-cultural diversity that characterizes modern urban areas, rooting on the valorization of differences within an inclusive society. In the perspective of smart city initiatives, it also stimulates the degree of participation by government, private sector entities and civil society. Talent is measured by the presence of creative people, but, according to Glaeser (2002), it can also be captured by the level of human capital, and, in particular, by the availability of a highly educated workforce. Moreover, we introduce tourism and urban amenities as measures of urban attractiveness driven by arts, natural and cultural heritage, and recreational activities. This is also consistent with the "consumer city" approach (Glaeser et al., 2001), or amenity view (Poelhekke, 2006), that emphasizes the great varieties of services and consumer goods provided in the cities, such as the density of restaurants and libraries and the supply of public services per capita, as attractive and retaining factors for educated and skilled households. Trying to merge these theoretical and applied insights in the cultural dimension, we derive an articulated set of indicators. Driving Force indicators deal with the age structure of the population and its level of educational attainment, which is unequally distributed across cities of the same country. Pressure indicators measure the change in young and educated population change, together with the number of tertiary education students, with a separate indicator for female students. State indicators are given by the share of business and financial sector on the urban economy, and by the development of tourism, entertainment and cultural industries. Impact indicators measure the proliferation of new businesses, the diffusion of local units providing business services, and the intensity of tourism supply. Response indicators concern the diffusion of libraries, the use of digital services by local governments (as a proxy of e-government), and the proportion of women elected in local councils (as a proxy of gender policies).

After having omitted redundant indicators and those indicators whose values are missing for too many cities, we end up with 23 environmental indicators, 22 social indicators, and 21 cultural indicators. For those indicators that are not available for the 2007-2009 period, we refer to data coming from the previous waves of the survey. Although missing data are a serious drawback of this exercise (for instance, data on French cities are missing in most of the cases), the number of observations is still considerable, ranging from 78 to 202 cities, and covering a population from 30 to 80 million of residents.

6. Methodology

Once selected the indicators, we perform a principal component analysis (PCA) for each step of DPSIR model followed by an orthogonal rotation and select those components explaining at least 75% of variance[7]. In this way we identify the most crucial characteristics of the European cities with respect to their *ex ante* capabilities of activating and effectively implementing smart city initiatives. Then, we carry on a two-step cluster analysis by applying stopping rules based on Calińksi-Harabasz pseudo-F and Duda- Hart pseudo-T-squared values. In this way we find out the appropriate number of clusters of cities for each step of the model. By using this methodology we highlight strengths and weaknesses of European cities in a comparative and inter-related perspective. Which aspects should eventually prevail, it depends on cities' objectives and residents' needs and wants.

[7] Detailed results of PCA are available upon request.

7. Results

7.1 Environmental dimension

PCA on environmental indicators generates 12 components. Each step of the model is described by two components. Most of the components are associated with Smart Environment, whereas the other ones are primarily referred to Smart Mobility.

According to cluster analysis (Table 1) medium-sized cities in Germany, Belgium and The Netherlands are characterized by a high level of accessibility (ACCES). These cities have traditionally been able to face the outward expansion of the population and the increasing complexity of the pattern of economic and social activity by improving the levels of mobility via public transport. Conversely, Italian cities are characterized by the dominance of private transport. In terms of Pressure indicators, Polish and small German cities are virtuous in limiting natural resources consumption (RES1, RES2), whereas water consumption is generally higher in southern Europe. State indicators are healthier in continental and northern European cities, especially in those ones that enjoy structural advantages (such as low population density) combined with appropriate mobility policies. On the one side, waste landfilling is minimum in a heterogeneous group of cities (WAS) that involves six different countries (Germany, Belgium, Austria, The Netherlands, the UK, Italy). On the other side, smartness and sustainability in air pollution aggregate four British small and medium cities together with the two main Swedish cities (Stockolm and Göteborg), Lisboa and Salzburg (POLL). Impact clusters confirm the positive conditions of German and Swedish cities in terms of a combination between premature mortality and road accidents outcomes (HEAL). Finally, the smartest Response cluster is dominated by a four German cities (Dusseldorf, Leipzig, Berlin, Dortmund) characterized by a virtuous combination of large transport networks, high proportion of waste recycling and large green areas per capita (GREEN). However, the limited number of selected cities for the Response step caused by missing data bounds the significance of this result.

Environmental indicators also show that, together with geographical factors, size proofs to be an agglomerating feature of European cities. However their correlation with the selected indicators is twofold. On the one hand, it is positively related to those components that are related to public transport and mobility management because of the diffusion of multimodal networks in larger cities. On the other hand, it is negatively associated with environmental-based indicators thanks to the advantage in air pollution and green areas attached to small urban areas.

<Table 2>

<Table 3>

7.2. Social dimension

PCA on social indicators generates 12 components. Their distribution throughout the different steps of the model is concentrated in Driving Force and Pressure fields, each of which is explained by three factors.

Cluster analysis (Table 2) highlights that the low proportion of young people depresses Driving Force indicators of German cities, together with those of Athina and Luxembourg. Conversely, Dutch and Belgium cities have a high potential in terms of social smartness (YOUNG). Pressure is more sustainable in those cities that are characterized by a low percentage of immigrants coming from low developed countries and by a small number of business crises, and, therefore, that have a high integration potential (INTEG). However, in almost all countries we find a large urban population change, both in size and sign. Large cities are usually put under pressure by external demographic pressure and inward migration from non EU countries much more than small ones. State clusters identity a group of small and medium German cities reporting the best results in terms of both employment (quantitatively and qualitatively), and housing conditions (WEAL). In other countries, however, these indicators are attached to considerable within-country heterogeneity due to geographical and social disparities. In particular, no matter which country is taken into account, the larger is the city in terms of population, the less space citizens have at their disposal. Impact indicators highlight the unsafe conditions that characterize many cities of the UK and Portugal characterized by the weaknesses of local economies and the increasing inequality of economic, social and living conditions. On the other hand, a substantial number of Italian urban areas are traditionally affected by a high number of thefts. Instead, Eastern European cities are joined together through the combined use of these indicators, showing the lowest social impact (SAFE1 and SAFE2). Again, the composition of

Impact clusters confirms that the size of the urban area is an important variable in determining the outcome of agglomeration process. Finally, most responsive cities in terms of social services are grouped in Germany and Sweden (SOC1, SOC2, SOC3), although, as we have just seen, they are exposed to high social pressure. Conversely, Italian cities suffer from poor policy response, although with some exception. When analyzing the relationship between Response and Pressure indicators, however, a useful precaution is to acknowledge that change in demographic and housing indicators are very slow. Therefore, social segregation tends to become structural and policy intervention can hardly modify this trend.

<Table 4>

<Table 5>

7.3 Cultural dimension

PCA on cultural indicators derives 13 components. The wide variety of issues covered by the cultural domain keeps the number of explaining factors relatively high compared to the number of indicators.

According to cluster analysis (Table 3), the most advantaged conditions in terms of Driving Force and Pressure are reported in Scandinavian, German and British cities (EDU1 and EDU2, HC2). In particular, Cambridge and Nottingham achieve top ratings in human capital related indicators. Positive results in terms of Pressure are also reported by a small group of eastern European cities (HC1) thanks to the high number of students in tertiary education. In terms of State indicators, cities that can be classified as both touristic and "creative" are mainly located in Germany and, to a limited extent, in Italy (CREA1, CREA2). The best mix of Impact indicators is attached to a cluster composed by four cities, all located in the Benelux (INN1). These cities are characterized by both a sustained growth of new businesses, and a high level of tourism supply. In the meanwhile, the combination of entrepreneurship with the supply of ICT services is remarkable in Scandinavian, Romanian and Dutch cities (INN2). These clusters actually identify those systems that addressed change through entrepreneurship, innovative services and tourist receptivity of the urban area. Finally, Response clusters look as the most volatile and unpredictable groups as the latent indicators are less related to cities' economic structure than the other ones due to their soft nature. The leading clusters include both large and small cities that are quite evenly distributed across Europe. On the one side, the best results in women's political participation are achieved by a group of 10 cities (GOV) belonging to four different states (UK, Germany, Spain, and Finland), whereas all Italian cities are characterized by low female participation in the decision making process. On the other side, e-government is mostly developed in five cities (Aberdeen, Krakow, Nowy Sacz, Reggio Calabria, Turku) that form an original and geographically dispersed cluster (E-GOV1).

<Table 5>

<Table 6>

8. Discussion

One of the main peculiarities of the smart city concept is that a successful, sustainable and inclusive urban development can be only achieved through a balanced mix of accomplishments in different fields in order to enhance citizen's welfare in a holistic and sustainable way. In this respect, our ex ante assessment lead to a thorough comparison of the needs and potential of European cities before the kick-off of Europe 2020 strategy, and relate them to the policy responses that have been adopted by the communities. Accordingly, our results are useful for pointing out those cities that have achieved satisfactory results along the three dimensions of interests at the outset of Europe 2020 strategy. Since the concept of smart city entails policy initiatives addressing one or more issues attached to a forward looking vision of urban areas, we look at the relationship between policy indicators and those variables that drive the targets in each dimension. In particular, as policy actions trigger reactions and feedbacks within urban systems, we take benefit from the DPSIR model by analyzing the results of Response and Pressure indicators and their relationship.

At a first glance results draw a quite mixed picture of European cities. First, the groups of smart and sustainable cities are highly heterogeneous with respect to population, economy, social conditions, and cultural development. Second, our analysis confirms that the largest urban areas are not the leading town of the continent, in line with the evidence that low concentration of European urban structure is associated with the absence of strong agglomeration economies that push population and economic activities towards metropolitan area (Dijkstra et al., 2013). Accordingly, it is not possible to aggregate those towns that fruitfully combine a high potential with a remarkable policy response in homogeneous groups.

Notably, at national level, the only country that is represented in all the three dimensions both in terms of Pressure and Response is Germany. In particular, we find that East German cities are the ones that present the most balanced outcome. Leipzig is well positioned along both environmental and social dimensions, while Berlin and Dresden are included in three clusters: the former is well performing in environmental and social dimensions, while the latter achieves satisfactory results in social and cultural dimensions. On the other hand, a part of Scottish towns show the best combination between social and cultural sustainability, which is likely to be obtained by activating place-based policies that stimulates the attractiveness of the area for young educated population. For these cities, however, two facilitating factors are also in place. First, as they are less wealthy than other parts of their countries, the presence of diminishing returns from the supply of public services with respect to the level of wealth may have favored the magnitude of the relationship between policy indicators and Pressure variables along the social dimension. Second, the higher relative endowment of natural resources and amenities is positively related to the higher degree of smartness and sustainability of these cities along the environmental dimension.

Another country that shows successful combinations of Response and Pressure indicators, at least in the social dimension, is Sweden. All Swedish towns, including Stockolm, Goteborg and Malmo, achieve satisfactory results along this dimension thanks to the high supply of public services and the favorable demographic structure that allow these cities to act as places of integration of new immigrants that seek citizenship of their new country of residence.

Looking at single cities, the most remarkable result is actually achieved by Leipzig which is the only city that combines smart Response and Pressure indicators in two fields. This outcome is consistent with the urban regeneration of the city further to the Urban Community Initiative which transformed this declining town in a model of redevelopment (European Commission, 2010b). Another worthwhile case is Malmo which during the 2000s has been characterized by a considerable economic dynamism after having experienced a deep and difficult transformation during the previous decade. Finally, two single cities emerge outside Germany, Scotland and Sweden: Krakow and Sheffield. The former has been able to combine the presence of a growing stock of human capital with the development of e-government systems aimed at supporting the large touristic flow. The latter presents a high level of gender equality in the representation of political authorities, together with a remarkable share of young aged population and a well-developed system of e-government.

<Figure 1>

<Figure 2>

<Figure 3>

<Figure 4>

<Figure 5>

<Figure 6>

9. Conclusions

In order to become smart, a city must look for a balanced development of both physical and intangible infrastructures under a proper institutional framework. Such a path is, however, subject to environmental, social, and cultural constraints as well as opportunities. This is especially true in the European context, where one of the goals of EU urban policies is the reduction of spatial disparities and the promotion of inclusiveness in accordance with the sustainability principle. However, both notions of smartness and sustainability are complex, while their pursuit implies long-term objectives and indicators**,** which are at odds with short-term and sectorial targets. The rhetoric of smartness runs the risk of losing a critical approach on the enthusiastic and celebratory images illustrated by the techno-centered vision, while at the same time, it has the advantage to emphasize multidimensionality as the key factor for a fruitful analysis of the drivers of urban development in the knowledge economy. In view of that, it can be useful to combine smartness and sustainability together when the policy maker has to interpret data in a meaningful and consistent manner with respect to Europe 2020 objectives. In this perspective, it is also crucial to take into account of a wide array of indicators and to provide an *ex ante* assessment of European cities in a multidimensional perspective, given that the effectiveness of smart city projects necessarily ground on the initial conditions of the involved areas as assessed by a comprehensive baseline measurement system.

Setting up a new bundle of indicators that provide a conceptual novelty compared with other rankings may help in understanding the relationship among economic crisis, sustainability objectives, and inequality issues in urban contexts. In order to become smart and sustainable, cities needs a fertile environment guided by responsive administrators. Such indicators should facilitate a comparative assessment as policy solutions should "circulate, migrate and mutate on an international scale and with growing speed" (Vanolo, 2014, p. 886), while acknowledging that the evaluation of urban areas also depends on local context, on administrators' vision, and, more generally, on idiosyncratic cities' challenges.

By keeping this in mind, and following the DPSIR model, which has been created for addressing sustainability issues, we derive a multi-dimensional set of indicators able to keep together short-term and long-term issues. In this way we put in relationships the different aspects of the smart city concept under three dimensions: environmental, social and cultural. Within each domain our proposal takes into account pillars that are crucial to achieve both smartness and sustainability targets: demography, pollution, mobility, health, education, crime, living conditions and digital services. This approach can be at the root of possible future developments of appropriate methods and indicators for measuring the success of smart cities initiatives at European level.

Basically, the results are threefold. First, in terms of geographical distribution our clusters of smart and sustainable cities are quite heterogeneous. At social and environmental level they are consistent with the *ex post* evidence that most prominent examples of smart city solutions arising from local government procurement and close interactions with utilities and academia have been found in Scandinavian and German cities (Carvalho et al. 2012; Dewald and Truffer, 2012). Conversely, the soft nature of the indicators is at the root of the remarkably assorted groups of smart and sustainable cities in the cultural dimension, among which Scottish town stand out. For the same reason, however, such a cultural baseline could be very useful for appreciating the future impacts of smart city projects. Second, in terms of cities' size, a substantial group of small and medium cities enjoy structural advantages in terms of all the three dimensions, except for mobility related indicators. These cities are acknowledged to be a benchmark of sustainable urbanism, combining human scale and livability with knowledge production and innovation. Accordingly, they are the ones that may benefit from further investment in smart projects provided their satisfactory sustainability standards that put them in the conditions to take advantage from appropriately targeted projects. On the opposite side big cities suffers from high pressure in both social and environmental domains, while their cultural potential is not accompanied by a supportive policy action in the field of digital services offered by local authorities. This outcome thus confirms that the pattern of urban development in Europe does not follow a linear path driven by the large city logic. Third, side by side to cities traditionally characterized by high levels of sustainability and high standards of living, there are several cities with high potentials in specific steps or dimensions. Although they are neither core cities nor they are located in the core regions of the continent, these cities are agglomerated in smart clusters (especially cultural ones) that go beyond the traditional North-South divide.

The main implication is that policies at different levels should not focus only on core urban areas, but they should leverage on the potential of small and medium cities outside the core regions through interventions benchmarked on the successful initiatives of cities belonging to the same clusters. Urban policies could thus be tailored to local needs and opportunities without abandoning the most challenging goals and priorities attached to the smart city concept. Not only the knowledge of space-specific characteristics affects the effectiveness of these policies, but also the awareness of the level of proximity with other urban areas in each relevant domain is a crucial factor in preventing their failure.

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Table 1. A selection of "smart city" definitions

Author (s)	**Source**	**Definition**
Hall (2000)	Urban studies	A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens
Giffingher et al. (2007)	University of Vienna	A Smart City is a city well performing in a forward-looking way in six characteristics (Economy, People, Governance, Mobility, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens.
Komninos (2008)	Intelligent cities and globalization of innovation frameworks	Smart cities are territories with high capacity for learning and innovation, which is built in the creativity of their population, their institution of knowledge creation, and their digital infrastructure for communication and knowledge management.
Hollands (2008)	City	A city centered on the utilization of networked infrastructure to improve economic and political efficiency and enable social, cultural and urban development
Lombardi et al. (2012)	Innovation: The European Journal of Social Science Research	A smart city therefore has smart inhabitants in terms of their educational grade. In addition, the term is referred to the relation between the city government administration and its citizens. Good governance or smart governance is often related to as the use of new channels of communications for the citizens, e.g. "e-governance" or "e-democracy"
Harrison et al. (2010)	IBM	A city "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city.
Nam and Pardo (2010)	Annual Conference on Digital Government Research	A city is smart when investments in human/social capital and IT infrastructure fuel sustainable growth and enhance a quality of life, through participatory governance.
Washburn and Sindhu (2010)	Helping CIOs Understand "Smart City Initiatives"	The smart city is a collection of smart computing technologies applied to the seven critical infrastructure components and services.
Toppeta (2010)	The Innovation Knowledge Foundation	A city "combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability.
		The city
Lombardi et al. (2012)	Innovation: The European Journal of Social Science Research	A smart city therefore has smart inhabitants in terms of their educational grade. In addition, the term is referred to the relation between the city government administration and its citizens. Good governance or smart governance is often related to as the use of new channels of communications for the citizens, e.g. "e-governance" or "e-democracy"
Caragliu and Del Bo (2012)	Journal of Urban Technology	A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.

Table 2. Environmental indicators after PCA.

Components	N	% var.	Description	Indicators	DPSIR
1D. CITY_ACC	178	51%	City accessibility	i. Rail accessibility (2003-2006), ii. Multimodal accessibility (2003-2006).	Driving force
2D. PRIV_TRANS	178	34%	Diffusion of private transport means	i. N. of cars per 1000 pop ii. N. of motorcycles per 1000 pop	Driving force
1P. RES_CONS	142	55%	Consumption of resources	i. Water consumption (m3 per annum) per inhabitant ii. Collected solid waste per inhabitant and year	Pressure
2P. WAT_PRICE	142	31%	Water price	i. Price of a m3 of domestic water	Pressure
1S. POLL_AIR	108	50%	Air pollution	i. N. of days Pm10 exceeds 50 µg/m³ per year ii. Annual average concentration of NO2 iii. N. of days ozone exceeds 120 µg/m³ per year	State
2S. WAS_LAND	108	24%	Landfilled waste	i. Share of solid waste processed by landfill	State
1I. MOR<65	176	54%	Mortality rate for <65 related to heart diseases and respiratory illnesses	i. Mortality rate for <65 ii. Mortality rate for <65 due to heart diseases and respiratory illnesses	Impact
2IROAD_ACC	176	31%	Deaths and injuries in road accidents	i. Deaths in road accidents per 10000 population ii. Persons seriously injured in road accidents per 10000 population	Impact
1R.TRANS_NETW	85	42%	Transport network	i. Length of public transport network divided per land area ii. Stops of public transport per km2	Response
2R. GREEN_SER	85	37%	Green services	i. Length of public transport network per inhabitant ii. Green space (in m2) per capita iii. Share of solid waste processed by recycling	Response

Table 3. Smart and environmentally sustainable clusters.

Cluster	Features	Main cities	Countries (number of cities)
a) Driving Forces			
ACCES	Very high multimodal and railway accessibility. Low diffusion of private cars and motorcycles.	Bruxelles, Antwerpen, Gent, Liège, Berlin, Hamburg, München, Köln, Frankfurt, Dortmund, Düsseldorf, Bremen, Hannover, Nürnberg, Bonn, Den Haag, Amsterdam, Rotterdam, Utrecht, London, Leipzig, Wien, Birmingham	Belgium (6), Germany (28), The Netherlands (9), Austria (1), UK (4)
b) Pressure			
RES1	Low water consumption and low amount of collected waste. Low water fares.	Lodz, Krakow. Gdansk, Poznan, Wrocław	Poland (24), Latvia (1), Germany (1)
RES2	Low water consumption and low amount of collected waste. High water fares.	Bruxelles, Frankfurt, Berlin, Gent, Liège, Dortmund, Leipzig	Germany (27), Belgium (5) Poland (1). Austria (1), Sweden (1)
c) State			
POLL	Very rare air pollution. Very low proportion of solid waste processed by landfill.	Salzburg, Lisboa, Göteborg, Nottingham, Stockholm	UK (4), Sweden (2), Portugal (2), Austria (1)
WAS	Rare air pollution. Very low proportion of solid waste processed by landfill	Trieste, Gent, Liège, München, Dortmund, Düsseldorf, Rotterdam, Wien, Linz, Birmingham	Germany (3), Belgium (3), Italy (2), Austria (2), The Netherlands (1), UK (1)
d) Impact			
HEAL	Low mortality rate for persons aged <65 from heart diseases and respiratory illnesses. Small number of persons seriously injured in road accidents	Hamburg, München, Köln, Frankfurt, Stuttgart, Dresden, Bonn. Luxembourg, Stockholm, Malmö,	Germany (15), Sweden (5), UK (5), Italy (4), Luxembourg (1)
e) Response			
GREEN	Large transport network. High proportion of solid waste processed by recycling. Large green space per capita	Düsseldorf, Leipzig, Berlin, Dortmund	Germany (4), Italy (2),

Table 4. Social indicators after PCA.

Components	N	% var.	Description	Indicators	DPSIR
1D. DEM	120	47%	Demography	i. Share of pop aged 75+ ii. Demographic dependency i. Share of pop aged 0-4	Driving force
2D. IMM	120	19%	Immigrants and females	i. Female to male proportion ii. Non-EU nationals as a proportion of pop	Driving force
3D. HOU_HOL	120	15%	Household size	i. Persons per household	Driving force
1P. POP_TREND	92	42%	Population trend	i. Pop change over 1 year ii. Pop change over 5 year	Pressure
2P. MIGR_NONEU	92	24%	Migration from non-EU countries	i. Share of nationals that have moved to the city during the last two years ii. Share of non-EU Nationals that have moved to the city during the last two years iii. Share of non-EU Nationals and citizens of a country with a medium or low HDI	Pressure
3P. CRISIS	92	17%	Business crisis	i. Share of companies gone bankrupt	Pressure
1S. UNEMPL	118	53%	Unemployment and low human capital endowment	i. Unempl. rate (1999-2002) ii. Share of working age population qualified at level 1 or 2 ISCED (1999-2002)	State
2S. HOUS_NEED	118	22%	Basic housing needs	i. Share of dwellings lacking basic amenities (1999-2002) ii. Share of overcrowded households (1999-2002)	State
1I. CRIM	202	49%	Urban crime	i. Recorded crimes per 1000 pop ii. Domestic burglaries per 1000 pop	Impact
2I. THEFTS	202	32%	Thefts	i. Car thefts per 1000 pop	Impact
1R. PUBL_GOODS	148	49%	Health services, education	i. Share of employment in public administration, health, education ii. Children 3-4 in day care per 1000	Response
2R. CHILD	148	28%	Children daily care	i. Children 0-2 in day care per 1000	Response

Table 5 Smart and socially sustainable clusters.

Cluster	Features	Main cities	Countries (number of cities)
a) Driving Forces			
YOUNG	High proportion of young people	Bruxelles, Antwerpen, Wien, Den Haag, Amsterdam, Rotterdam,	The Netherlands (11), Belgium (4), Austria (1)
b) Pressure			
INTEG	Low number of immigrants coming from countries with a medium or low HDI. Demographic growth. Small number of business crises	Dresden, Tampere, Stockholm, Göteborg, Malmö, Leipzig	Sweden (7), Germany (4), Finland (2)
c) State			
WEAL	Full employment. Low proportion of low qualified workforce. Low proportion of dwellings lacking basic amenities and of overcrowded households	Bonn	Germany (3)
d) Impact			
SAFE1	Very low crime rate. Small number of thefts.	Varna, Zaragoza, Warszawa	Poland (16), Hungary (5), Bulgaria (5), Slovakia (2), Latvia (1), Spain (1), Italy (1), Malta (1)
SAFE2	Low crime rate. Small number of thefts.	Riga, Kaunas, Valletta, Krakow, Trieste,	Poland (6), Italy (2), Slovakia (2), Bulgaria (2), Slovenia (1), Latvia (1), Lithania (1), Estonia (1), Malta (1)
e) Response			
SOC1	Very high supply of public services, health , education. High diffusion of day care services for children aged 3-4 e 0-2.11	Ljubljana	Germany (5), Sweden (4), Slovenia (1)
SOC2	High supply of public services, health , education. High diffusion of day care services for children aged 3-4.	Dresden, Leipzig, Edinburgh, Aberdeen	Germany (5), UK (2) Slovenia (1)
SOC3	High supply of public services, health , education. High diffusion of day care services for children aged 3-4 e 0-2.	Berlin, Stockholm, Göteborg, Malmö,	Sweden (3), Germany (3)

Table 6. Cultural indicators after PCA.

Components	N	% var.	Description	Indicators	DPSIR
1D. ACT_POP	144	52%	Active population	i. Share of pop aged 15-64 ii. Share of pop aged 25-34	Driving Force
2D. HUM_CAP	144	25%	Human capital	i. Share of pop aged 20-24 ii. Share of pop aged 15-64 qualified at tertiary level (ISCED 5-6)	Driving Force
1P. HUMCAP_GROW	168	51%	Human capital growth	i. Students in tertiary education per 1000 pop ii. Students in higher education (ISCED 5-6) per 1000 pop aged 20-34 iii. Change in the proportion of pop aged 25-34	Pressure
2P. FEM_STUD	168	26%	Proportion of female students	i. Share of female students in higher education (ISCED level 5-6)	Pressure
1S. PER_SERV	152	39%	Personal services	i. Share of employment in trade and restaurant industry	State
2S. ATTR	152	29%	Attractiveness	i. Overnight stays per year per pop ii. Share of employment in culture and entertainment industry	State
3S. KIS	152	21%	Knowledge intensive services	i. Share of employment in financial intermediation and business activities	State
1I. ENTR	78	47%	Entrepreneurship	i. New business registered ii. Local units providing ICT services per 1000 companies	Impact
2I. TOURSUPP	78	31%	Tourism supply	i. Available beds per 1000 residents	Impact
1R. TOLER	163	42%	Role of women in public offices	i. Women elected city representatives per 1000 residents ii. Libraries per 1000 residents	Response
2R. E-GOV	163	25%	Digital services offered by local authorities	i. Administrative forms that can be submitted electronically (2003-2006) ii. Daily internet visits on the official site	Response

Table 7. Smart and culturally sustainable clusters.

Cluster	Features	Main cities	Countries
a) Driving Forces			
EDU1	High share of active and young population. High number of people holding a university degree	Kaunas, Glasgow, Stockholm, London, Göteborg, München, Frankfurt, Thessaloniki, Aberdeen	Germany (5), Greece (4), UK (3), Sweden (2), Finland (1)
EDU2	High share of active and young population. High number of people holding a university degree.	Tampere, Cardiff, Newcastle upon Tyne, Leeds, Manchester, Edinburgh, Nottingham, Cambridge	UK (10), Sweden (2) Finland (2)
b) Pressure			
YOUNG EDU1	Increasing share of young population. High number of students in tertiary education.	Warszawa, Krakow, Katowice, Cluj-Napoca	Poland (10), Slovakia (2), Estonia (1), Romania (1)
YOUNG EDU2	Increasing share of young population.	München, Köln, Liverpool, Edinburgh, Manchester, Dresden, Cambridge	Germany (8), UK (8), Hungary (1), Slovakia (1),
c) State			
CREA1	High weight of tourism, culture and entertainment sectors. Very high weight of financial and professional services. Very high tourism demand.	Frankfurt, Düsseldorf, Rome, Milan	Germany (2), Italy (2)
CREA2	High weight of tourism, culture and entertainment sectors. High weight of financial and professional services. High tourism demand.	München, Stuttgart, Leipzig, Dresden, Stockholm	Germany (8), Sweden (1)
d) Impact			
INN1	High entrepreneurship. Very high supply of ICT services. High tourism supply.	Bruxelles, Antwerpen, Luxembourg, Amsterdam	Belgium (2), The Netherlands (1), Luxembourg (1)
INN2	High entrepreneurship. High supply of ICT services.	Gent, Liège, Vilnius, Den Haag, Rotterdam, Utrecht Bucuresti, Cluj-Napoca, Timisoara	Romania (4), Finland (3), The Netherlands (3), Belgium (2), Lithuania (1),
e) Response			
GOV	High share of women elected city representatives. High development of e-government.	Nürnberg, Barcelona, Zaragoza, Bilbao, Salzburg, Bremen, Birmingham	Spain (4), Germany (2), UK (2), Austria (1), Finland (1)
E-GOV1	Very high development of e-government.	Krakow, Aberdeen	Poland (2), Finland (1), UK (1), Italy (1)
E-GOV2	High development of e-government.	Bonn, Vilnius, Katowice, Leeds, Edinburgh, Bochum, Lodz,	Poland (8), Germany (5), UK (3)

Figure 1 – Environmental Pressure - Smart and sustainable clusters

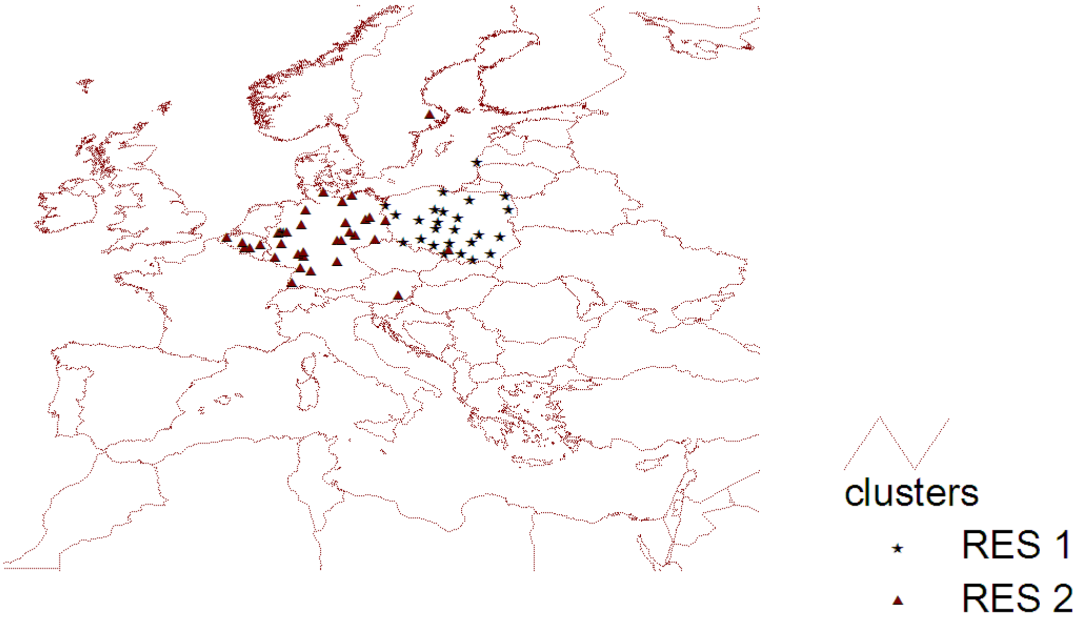

Figure 2 – Environmental Response - Smart and sustainable clusters

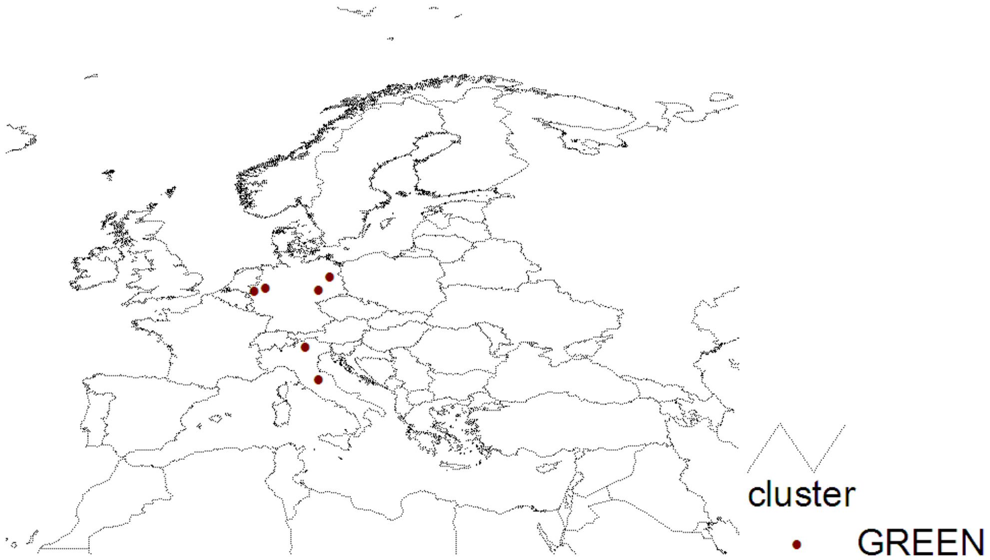

Figure 3 - Social Pressure - Smart and sustainable clusters

Figure 4- Social Response - Smart and sustainable clusters

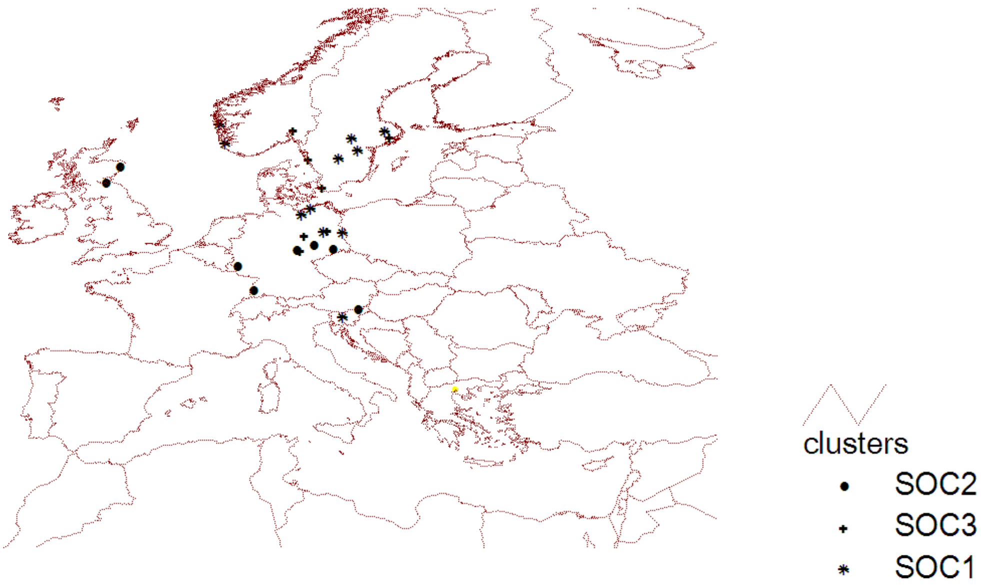

Figure 5 – Cultural pressure - Smart and sustainable clusters

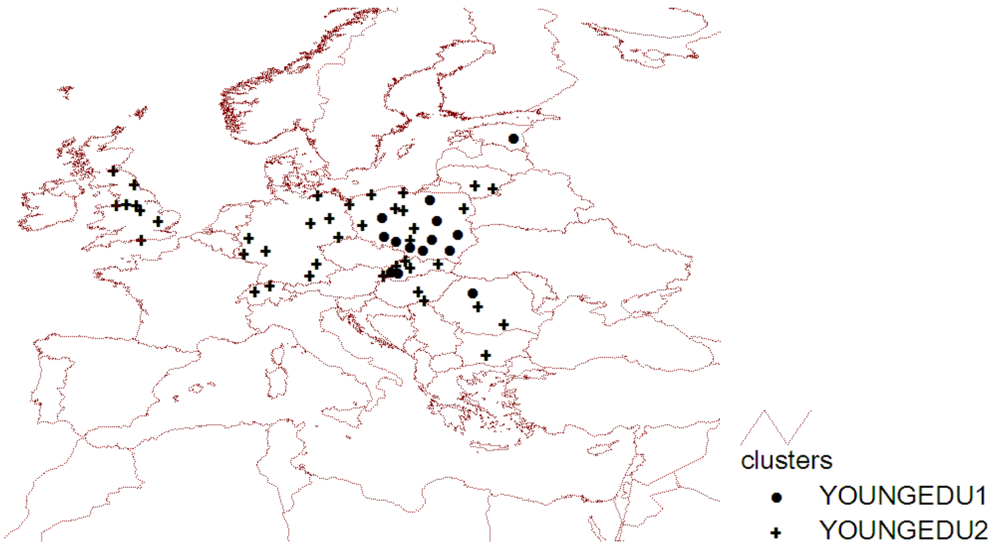

Figure 6 – Cultural response - Smart and sustainable clusters