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Defining Smart Cities: a Relative and Dynamic Approach

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1 ABSTRACT

Although the level of interest in smart cities is growing, the main issue – the smart city concept – is still open. The definition of smart city is not shared as well as the way to measure city's smartness. The main approach has developed the concept of an "ideal" city which every city should tend because it represents the optimal standard.

In this context, the aim of our paper is to break with the traditional point of view in favour of a new concept of smartness which identifies a city specific value of smartness, based on the efficient use of its own resources and related to the different context in which a city is situated. Thus, in this way, the concept of smartness becomes relative. Moreover when a city is very close to optimal value (i.e. maximum efficient frontier) then the frontier will shift upward because of the more attractiveness of the city but after a while the performance of the city goes down and a new adjustment mechanism should be followed to become efficient again (virtuous cycle). The needed time to be close again to the frontier will be correlated to the degree of inertia (reaction time) of urban government. So the smartness concept becomes dynamic as well as relative because it depends on how long the city takes to react and change the direction of its own performance to become smart again.

2 CITY'S SMARTNESS VS FIRM'S PRODUCTION

In these recent years, innovation processes, i.e. the application of knowledge, have been implemented mainly at the local level. Although the production of new knowledge is available on a global scale, only in a restricted territorial area collaborations among individuals are more effective. These innovation processes lead to the creation, hybridisation, and spread of knowledge and technology from the world of scientific research to production and services sectors and in a more broad way knowledge is spread about all citizens. Due to the gradual de-materialisation of the infrastructures, the progressive digitisation of innovation, the new forms of online learning and the advent of ever more virtual technologies, new theoretical models have emerged where innovation should be combined with talented people and with social cohesion at urban level.[1] Human capital, technology, and innovation are the main resources of a smart city. Moreover, the definition of smartness is widened by Caragliu, et al. (2009) where they consider the role of interconnected infrastructures to improve economic and political efficiency. A city, thus, should be business-friendly to attract and accommodate business projects, should stimulate the coexistence and complementarity of high-tech and soft infrastructure, and, finally, should promote the social and relational capital within the urban area.

From a concept related to energy saving and efficiency use issues, the smart city notion has been developed to include different aspects such as quality of life, environment, human capital, education, employment and so on. Consequently, smart city has become more close to the efficient assumption of a firm.[2] A city is smart not because is necessarily technological advanced but because is able to use in an efficient way all the available resources. In Figure 1, a comparison between firm's production and city's smartness is represented.

On the basis of the neoclassical theory, a firm can be considered as a black box, where the attention is primarily on inputs and outputs without deepening any knowledge of its internal workings. In this view,

[1] For a more detailed analysis of smart city see Auci and Mundula (2015).

[2] This assumption leads back to the concept of the "socio-economic metabolism" of human systems. This framework has been developed in the EU countries' official statistics especially in the last fifteen years to study the interactions between socio-economic systems and other dimensions. Concerning the environmental dimension, a Satellite Environmental Accounts System within National Accounting was constructed ad hoc and it is currently compiled by each EU country. According to the approach of the socio-economic metabolism, urban systems (considered at different territorial scale: nation, region or city) are compared to a living organism needing inputs (such as natural resource flows, capital, labor, energy, soil) either for its functioning and growth and to produce some results as output (such as products, services, waste and pollution) that can identify the degree of well-being of a system.

resources or inputs are selected with respect to the outputs that should be produced by a firm. The black box, even if is unknown, can be represented by a function where several inputs are combined to obtain the final goods or services. This analysis based on profit-maximizing assumption implies that firm's behavior is always efficient. Given market prices, a firm's owner chooses the optimal output to maximize its own profit.

Similarly, a city to be smart should use in an efficient way its own resources. These resources are necessary to obtain as "output" the optimal urban well-being for all citizens. In other words, city's resources are combined within the public governance to ameliorate the well-being at urban level. Following a well-being-maximizing assumption, the city's mayor should behave in an efficient way reaching a fair and sustainable output for all citizens. Given market and no-market prices, a city chooses the optimal output such as an optimal well-being level to maximize its own smartness level.

If smartness means, as in Giffinger et al. (2007), a "combination of endowments and activities of self-decisive, independent and aware citizens", then it comes straightforward the parallelism with a firm of the neoclassical theory. For this reason, the efficient combination of resources can be measured by a production function and the fair and sustainable output can be captured by a specific indicator such as UrBes or a measurement of happiness. The first indicator is preferred because is a wider concept which can capture different aspects of citizens' well-being.

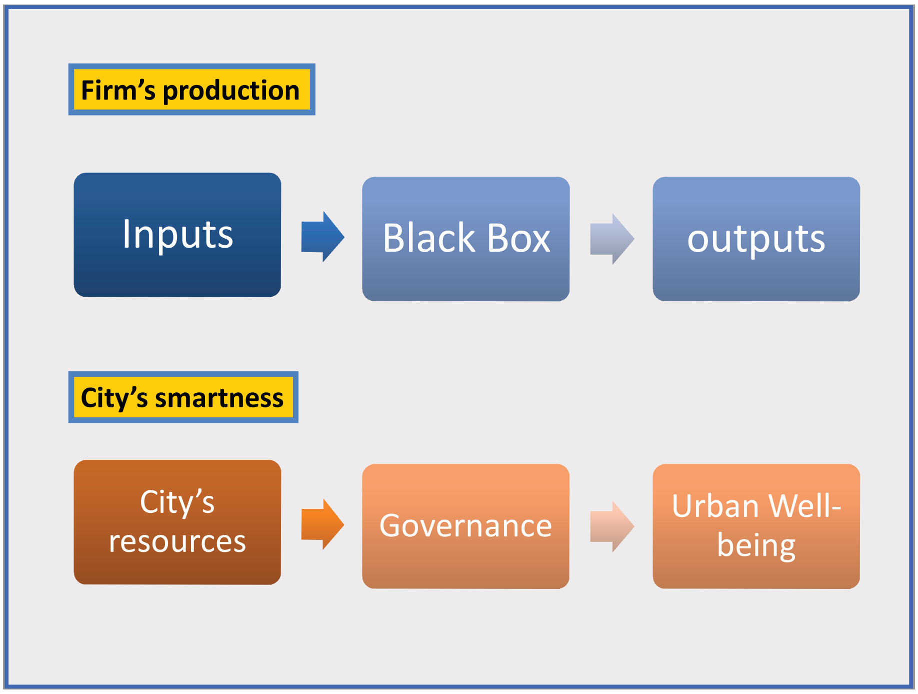

Figure 1: A comparison between firm's production and city's smartness

3 URBAN PRODUCTION FUNCTION AND URBAN RESOURCES.

Analysing urban efficiency is not a new debate. In fact, in the urban economy literature, urban efficiency is closely related to the so called "optimal city size". Urban size, considered as a target by government interested in efficiency of the urban system, can be reached when urban marginal costs are greater or equal to marginal benefits. This optimal point represents the way urban can contribute to national income (Alonso, 1971; Richardson, 1978). However, the optimal urban size is a threshold because before this maximum point net increasing returns to scale create positive externalities and the size of a city increases while beyond the maximum size negative externalities dominates and economies becomes diseconomies with net decreasing returns to scale. In this paradigm, the main hypothesis is that all cities have similar cost functions and production functions. The main result is that all cities search for a single urban size, optimizing costs, or incomes or net urban benefits. Actually, the common observation shows that city sizes are different and each city can reach a its own static or dynamic equilibrium.

Starting from the observation that cities perform different functions, are characterized by different specializations, and consequently operate with different resources, many criticisms arose against the theory of the optimal city size (Henderson, 1974, 1985, 1996). "We may expect the efficient range of city sizes to vary, possibly dramatically, according to the functions and the structure of the cities in question" (Richardson 1972, pp. 30). Similarly to firms, for which should be impossible to obtain the same output or income even if they can be identical in terms of inputs used, two cities cannot have the same size o level of population even if they start from the same level of resources.

The optimal level of urban size, in fact, may change over time because of exogenous shocks, a different industrial composition and the ensuing growing income curve profile, and the introduction of new technologies, with the consequent falling transport prices (Partridge, 2010).

Finally, Bechmann and McPherson, (1970) propose a model – the so called central place model – as an alternative between only one optimal size and infinite sizes where higher rank cities are expected to have a wider size with respect to lower rank ones, while cities belonging to the same rank show the same size.

Summarizing with the word of Camagni et al., (2013), "cities are supposed to share the same, complex cost and production functions with heterogeneous, substitutable factors linked not just to economic functions but to other context conditions. Therefore each of them maintains its specificity and consequently its 'equilibrium' size, but comparability (and possibility of running cross-sectional analyses) is saved and also possibility of devising policy strategies for urban growth or containment" (Camagni et al., 2013, pag 4).

Thus, the problem becomes to find the production function. To do that, we can consider that as the existence of a firm is related to positive transaction costs (Coase, 1937), the existence of a city is the result of human needs and objects. These necessities are strictly associated to three main categories of individuals who live in a city and represent the city's resources. As usual they can be subdivided in: families (residential and not residential), firms, and public institutions. In Figure 2, we show how these three categories are related each others.

Within the first group, residential families and city users or no residential families are included. Residential families mean only families that permanently live in the city while with city users all the individuals that are interested in coming in the city such as tourists or commuters are considered. The first need of a residential family is inhabiting within the city, but for both residential families and city users, buying goods and services from firms is also a necessity. In return, residential families and commuters supply their labour force to firms. For an entrepreneur producing near the market is its first necessity. A firm supplies goods and services but also builds houses for residential families and finally gives in return capital and labour income to families.

The main role of public institutions is the production of the so-called "public goods". Because these goods are non-rivalrous and non-excludable in consumption, there is a free-rider problem, meaning that a rational person has no incentive to contribute to the provision of the public good because he/she always gains benefits. Public institutions are necessary to firms, families, and city users even because they satisfy the need for a welfare state and infrastructures such as road-network, hydro-network, electric-network and so on and so forth. Firms, families, and city users paying taxes obtain in return all the public goods necessary for their transactions.

These three categories of individuals represent the resources of a city. From an economic point of view, the needs and objects of residential and no-residential families can be considered as inputs of a city's production function. Through the governance of public institutions these inputs are combined in an efficient way to obtain an optimal level of well-being for all citizens.

In Table 1, needs, targets and individuals of a city have a correspondence with the three main inputs of a firm (land, capital and labour). From the entrepreneur point of view, human, physical and financial capital, labour and land are the necessary inputs to maximize his own profit. Similarly, even for cities capital, labour and land represent the three main inputs of a production function to maximize the well-being of citizens to become more smart. For a city, land means the extension of the area in which citizens live and work. But which is the extension to consider? Should be considered the administrative or the contiguity area of a city? For the empirical analysis the administrative area is the more appropriate but the contiguity area should be more correct from a theoretical point of view. The contiguity area in fact can capture the congestion effect related to the neighboring areas that are attracted by the main areas of the city. Moreover, as already pointed out, several authors (Alonso, 1971; Richardson, 1978), according to the optimal size city theory, underline the link between city's extension and city's efficiency. They find that at the beginning an increase of the

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extension of the city means a raise of efficiency but after a certain point of extension, congestion, commuting and lack of adequate networks implies more inefficiency.

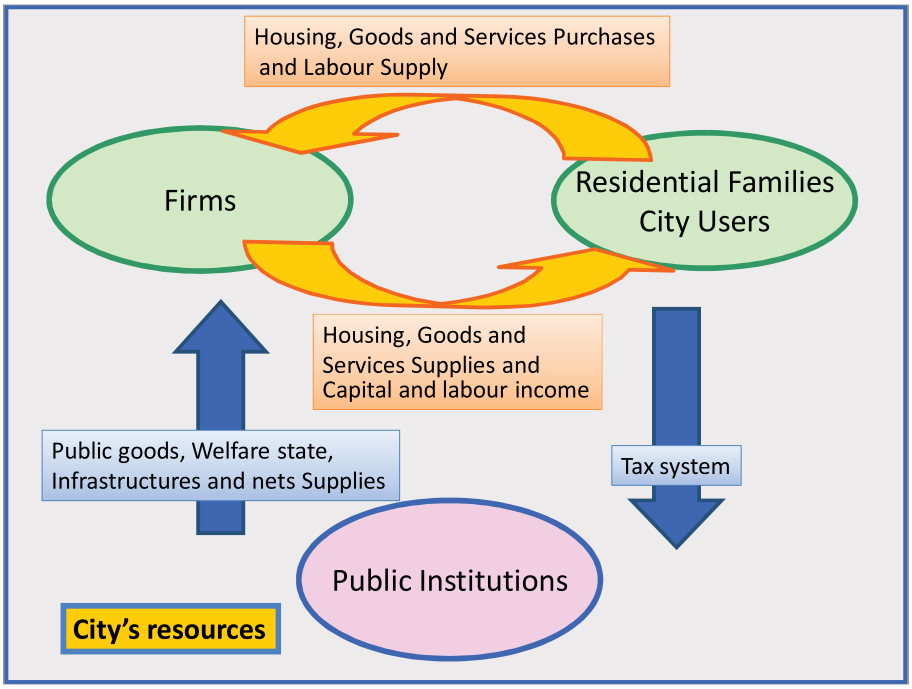

Figure 2: Model of the circular flow of income and expenditure of city's resources

In particular, analyzing a city from an economic point of view means considering a city like a unique entity maximizing its final object, i.e. the wellness of citizens. To describe a city's production function several variables representing the inputs should be considered. Starting from the primary needs of a society (inhabiting, producing and social provision) and crossing with the traditional productive factors as shown in Table 1, we can identify the inputs of the urban production function. So, because for residential families inhabiting is a primarily need, the surface per housing could be a good indicator for land input. Measuring land consumption could capture the extension of a city and this in turn can reduce the efficiency. At the same way subdividing capital into human, physical and financial allow to capture the different characteristics of the three typologies of individuals who live in a city.

NEEDS		**inhabiting**	**producing**	**social**
TARGETS		**utilities**	**profits**	**public goods**
INDIVIDUALS		**families and city users**	**firms**	**institutions**
LAND (La)		surface per housing (Sh)	surface per firms (Sf)	surface per public utilities (Sp=Stot-[Sh+Sf])
CAPITAL	Human (HK)	# of inhabitants (Ih)+ # tourists (T)+ # of commuters or temporary residential inhabitants (TIh)	# entrepreneurs (E)	# politicians (P)
	Physical (PK)	# of houses (apartment, villas, etc.) (H)	# of warehouses (small, medium and big) (W)	public infrastructures (PubInf) [networks (hydro, electric, roads, informatics, etc.), buildings (schools, hospitals, post offices, etc.)]
	Financial (FK)	labour income (LI)	capital income (CI)	public transfer payments (PubTr)+ tax payments (Tpay)
LABOUR (L)		underground economy (taking care of old men, children, houses, etc.) (UEc)	# of employees in the private sector (PrE)	# of employees in the public sector (PubE)

Table 1: The correspondence between city's resources and firm's inputs.

Thus, it is important to know not only the number of inhabitants or tourists of a city but even the number of commuters that every day come into the city for work. Moreover, both entrepreneurs and politicians represent a good resource for the city and its improving in well-being. As for physical capital, it could be measured by the number of buildings within the city both in terms of houses and warehouses, without forgetting the main role of public infrastructures of which good indicators should be constructed. Labour income, capital income, public transfer payments and tax payments should be useful to capture the financial capital within a city.

Finally, as regards labour inputs, the number of employees in the private and public sectors is the main indicator for capturing the role of firms and institutions of a city. A measure of underground work for family can be represented by the taking care of old men, children, houses and so on.

Finding a correspondence between city's behavior and firm's behavior is the basis for the analysis of the dynamic smartness of a city's performance. In other words, a city could be smart if and only if the use of all its resources is efficient. A city should behave like a firm and maximize its production function to reach its own target: a more high level of performance i.e. a more widespread urban well-being.

4 URBAN OUTPUT AS URBAN WELL-BEING

The progress of a social system occurs when an increase in social well-being is achieved. The final goal of a urban system is to obtain the highest collective well-being that represents the typical objective of a government. In accordance with this definition, in our view it is appropriate to consider as output of the urban production function the urban well-being that involves several domains. According to the system theory (Von Bertalanffy, 1968; Le Moigne 1977) an urban aggregate can be seen as a complex living system characterized by specific relations among its components and with the outside world. For this reason, sustainability issues have to consider simultaneously the internal sustainability of each dimension, the sustainability among different dimensions and the sustainability of the interactions between the system analyzed (country, region or city) and the outside world.

As well-being is a complex magnitude, UrBes statistical indicator (Urban equitable and sustainable well-being) developed and produced by Istat since 2014 seems a suitable measurement tool for the evaluation of the output of the urban production function. Because of its methodological characteristics, this indicator is useful to measure the relative smartness of a city - the new concept we propose in this paper - as the city's ability to use in an efficient way its own resources and to react to endogenous factors and exogenous shocks in order to move, as closer and faster as possible, to its own maximum efficient frontier by a new adjustment mechanism (virtuous cycle).

UrBes indicator has been developed applying definitions and methodologies used in the equitable and sustainable well-being indicator (Bes) project. This project was born from a joint initiative between Istat and National Council of Economic Labour (CNEL) in 2010 to measure the well-being of Italian society, as recommended by OECD tickled by the Stiglitz Commission Report. The Bes project also is part of the international debate on "beyond GDP" based on the awareness that parameters on which to assess the progress of a socio-economic system cannot be exclusively economic, but they should also take into account other key dimensions of the well-being, therefore accompanied by measures of inequality and sustainability.[3] Underlying the Bes, a list of 134 indicators has been set up and classified in 12 key-domains previously identified to capture the most significance aspects of well-being: Health, Education, Labour and life-time conflict resolution, Well-being, Social relations, Politics and Institutions, Security, Subjective well-being, Landscape and Cultural heritage, Environment, Research and Innovation, Quality of services. The result of this inter-institutional work was finally issued in 2013 with the first Report of Italian Equitable and Sustainable well-being (Bes). This initiative positions Italy in line with the most advanced international efforts to implement and develop a comprehensive measure of progress which goes beyond the quantitative metric on macroeconomic activities namely gross domestic product (GDP).[4] In particular, GDP appears an inadequate tool to evaluate progress of national and urban systems in terms of smart growth/development that in the last decade has also become one of the main EU policy objective. Concerning the measurement of well-being in the urban system, UrBes indicator has integrated some advanced information on well-being at city level strengthening the network of municipalities which participate to the UrBes project. In particular, the second edition of the UrBes Report (2015) the number of municipalities involved has increased from 15 up to 29[5] while the number of indicators used to measure urban well-being has grown from 25 provided in

[3] For this reason, due to the different dimensions involved, assimilating well-being to economic growth only represents an inaccuracy as well-being and GDP increase can be (partially) independent.

[4] ISTAT CNEL, Proposal for domains by the Cnel Istat Steering Committee on the measurement of progress in Italy, 26 September 2011 (http://www.misuredelbenessere.it)

[5] Along the national territory, the network of municipalities comprises ten Big Metropolitan Cities such as Torino, Genova, Milano, Venezia, Bologna, Firenze, Roma, Napoli, Bari and Reggio di Calabria. Moreover it comprises four Metropolitan Cities such as Palermo, Messina, Catania and Cagliari. Finally, it comprises other fifteen Municipalities

2014 to 54 in 2015.). This is due either to the availability of final data of the Census of 2011 and to the use of information from various statistical surveys previously unavailable.

Moreover, the report is accompanied by a summary sheet for each municipality participating in the UrBes project, that report general consideration on data and explore the theme of the relationship between the indicators and the specific political action planned in the specific urban context. In addition, in the Report 2015 there are also in-depth focus with which 12 municipalities have enriched the analysis of their chapter, including through the use of its administrative or statistical sources (surveys). The focus reported on sustainable mobility (Milan), school meals (Naples), management waste (Cesena), management of municipal services (Bologna and Reggio Emilia), involvement of minors and non-EU citizens in political participation in the elections of district (Brescia), labor market (Florence), the distribution of income and economic deprivation (Trieste and Prato), petty crime (Pesaro). These focuses are very interesting because they describe Italian living conditions along the territory and highlight great differences among italian cities - as expected - about the level of current well-being, critical issues in different dimensions, political decisions and availability of the set of data and information according to the phenomena investigated

Underlying the importance of the UrBes indicator methodology and of the results presented by Istat in the last Report of 2015, more efforts are necessary to complete the information in all the domains, to construct a homogeneous time series of data and to make more comparable the data especially at the spatial level to make this indicator a more effective tool for the analysis of the performance of the urban smartness.

5 MEASURING THE URBAN SMARTNESS: A NEW WAY

Having stated the UrBES index as output of the urban production function its important to underline that each city is different and the difference in terms of output is not only in terms of absolute value over the time, but also in terms of priority assigned to the different components of it. To solve this problem, each city' administration, through a survey, should ask to its citizen its preferences in order to assign a relative weight to each indicator of the UrBES index. The survey should be repeated at least every 5 years to capture the evolving needs of the population depending on the modification of the society' age structure and on the changing of the global (economic situations, social conflicts, cultural trends, and so on) context.

The first step in order to calculate the measure of the urban smartness is to define the path of the ideal urban performance in terms of relationship between output and production function. As argued in the previous paragraph, because there is not yet a synthetic measure of the UrBES index nor a full dataset that makes possible to calculate it with some statistical method (for instance OECD, 2008), we will describe the process merely from a theoretical point of view.

The trend of the ideal performance in the long run could have constant (linear), increasing (eg. exponential) or decreasing (eg. parabolic) returns of scale. This depends if there is, as assumed by growth theory, an infinite increase in productivity due to the potential of the human capital and technological innovation, rather than, as hypothesized by the degrowth or anti-capitalistic theories, a peak in the accumulation process of capital and then a decrease of the factor productivity due to a congestion effect. However in the short term we can assume to assume the path of the ideal performance of the production function is consistent with the neoclassical theory showing increasing returns to scale and therefore can be represented, using a Cobb-Douglas function with land, labour and (physical, human and financial) capital as main factors according to the variables showed in table 2. Finally, to find the ideal and optimal value of the urban production function it has to be maximized it under the constraint of efficient use of all the resources (i.e. for each factor, sum of the variable equal to 1). The ideal performance path has to be calculated for each city, because the values of the UrBES index are specific, as above argued, for each context.

The second step, to calculate the measure of the urban smartness, consist in defining the path of the actual performance of each city in terms of UrBES values. This path is sinusoidal because the inertia of the public administration contributes to diverge the actual performance from the ideal one while either the pressure of citizenship or the alternation of different parties to government (typical of a democratic system) or the dialectic of the majority, generate reactions to status quo, inverting, if is decreasing, the trend. The sinusoidal pattern, however, may be increasing, stationary or decreasing on average, depending on the adopted

such as Brescia, Bolzano, Verona, Trieste, Parma, Reggio Emilia, Cesena, Forlì, Livorno, Prato, Perugia, Terni, Pesaro, Potenza, Catanzaro.

solutions are more or less efficient in terms of performance. Moreover, given the increasing nature of the ideal performance, even a rising trend of the actual performance could be divergent from the ideal threshold.

From this point of view the benefits associated with an increase of city productivity inputs are only potential, that they are contingent upon the quality of management (i.e. the speed of reaction to exogenous shocks or internal pressures). Urban production function therefore defines an efficiency frontier, with effective efficiency often significantly below this frontier,. The distance between a particular point (that is a city actual performance) and the frontier is a measure of the quality of its management or, in other word, of the city smartness.

More in detail, having defined the two patterns, ideal and effective, of UrBES (see Figure 3) it's possible to evaluate the smartness of a city in terms of capability to react to a downgrade of its performance, defining:

- E actual reaction
- I ideal reaction
- E/I smartness
- $(E/I)/\Delta t$ dynamic smartness
- Δpx unexpressed potential at a given time
- $\Delta p1/\Delta p2$ potential reaction

A comparison among cities in terms of smartness, or better in terms of dynamic smartness, is no more based on resources endowment but it's relative to the distance from the actual performance to the ideal one (which is specific for each city) and to the speed with which the city reaches its maximum value of performance.

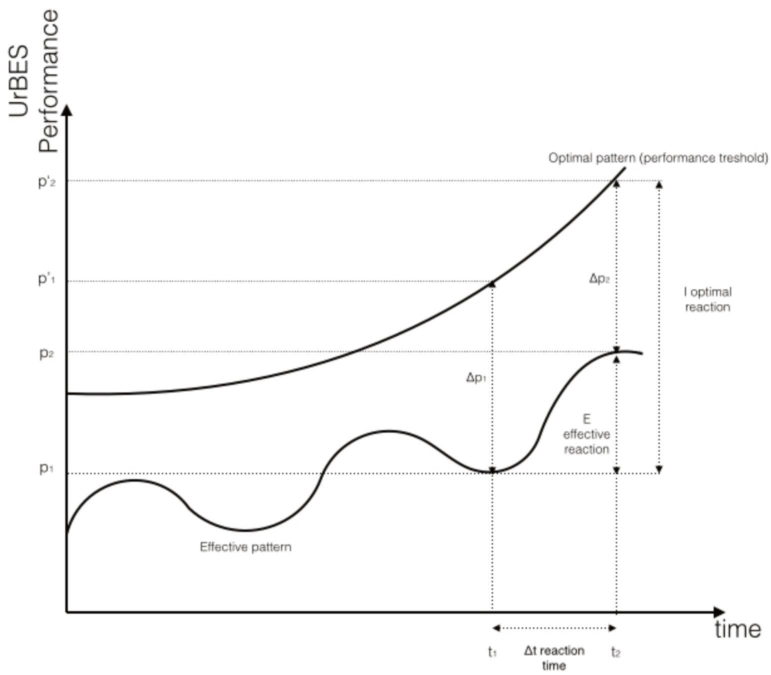

Figure 3: Dynamic smartness of a city's performance

6 CONCLUSIONS

The idea of Smart City is gaining consensus on the political and industrial and is about to become one of the central issues around which will be organized planning efforts not only of the major Italian and European cities, but also of many other forms of territorial aggregation. This trend is already materializing in a multitude of initiatives to transform the lives of millions of people, starting with simple projects that improve digital access to public services (such as the use of pc or smart phones to enjoy of a wide range of services), up to innovative infrastructures (i.e. to recycle waste water or for heating). However, even before being a set of technological solutions, the smart city is both the product of emerging social needs of urban scale, and the concrete manifestation of the need for a new generation of innovation policies: that is, it is a governance issue. The basic idea is that the great ability to access and processing of information offered by ICT technologies can contribute to building a community model much more cooperative than in the past, and therefore more "able" to pursue solutions more efficient, more competitive and more inclusive. The challenge is to combine in a single urban model environmental protection, energy efficiency and economic sustainability, with the aim of improving the quality of life of people who live there and create new services for citizens and for the public administrations, reflecting at the same time the different needs of the population without imposing a general structure. It has to be ensured that all social groups which form the urban centers are known in their behavioral patterns as these do not always confirm the stereotypes. It is important that cities are intelligent not in itself but for the people who live in.

In this perpective the measure of the smartness of a city should not be based on an ideal and homogeneous value, but rather on a relative value able of taking into account the specific endowments and resources of the different contexts and the identity of its inhabitants.

It is essential, therefore, that the different actors (local institutions, citizens and businesses), agree on the definition of smart city that they aim to achieve, that is, agree on objectives and on the definition of a medium-term strategy able to organize the various production factors of the city, in order to increase growth and ensuring happiness and welfare of the citizens. Such a perspective higlights the need for a new measure of the urban smartness, in order to choice which projects are more able to achieve it. Currently the various attempts that are moving in this direction are characterized by a single reference value to catch up and by a consequent ranking of cities in terms of distance from this ideal value. However, it seems evident that it is not only simplistic but conceptually incorrect to referring to an optimal value of smartness, unique and static that all cities should strive for. It must instead identify a specific value for each city, linked to its resources. This relative approach to the smartness concept shifts the study and analysis perspective on the subjective/perceptive component in order to take account of the fact that the same indicator has different value and weight in different contexts because of the historical memory (the genius loci, the milieu) of that context and of the identity of its inhabitants.

So what could be now called relative smartness it must also be a value strongly linked to the temporal dimension because when a given context will approach or reach to its optimum value, as maximally efficient (or nearly so), it will become more attractive so capturing new shares of the different forms of capital (social, physical, etc.). However, due to inertia (more or less marked) of the governance' action of each urban system, there will be a gap between the acquisition of these new inputs and the capacity of the same system in the handle efficiently. This will cause the cities to move away from the frontier of efficiency (or optimum value of relative smartness) previously identified. More precisely, given the new resources, it will be defined a new frontier that will result in a new adjustment path in terms of efficiency according to the new conditions (in this sense such a dynamic relies bonth on the theory of optimal size of the city ond of the business cycles).

From the above it appears clear that the lower the amount of time a given context will employ to adapt to the new conditions the more efficient in using their resources it will be. Here then emerge the dynamic character, as well as relative, of the smartness which can then be identified in the time in which a city takes to reach its efficient frontier (function of its resources) in the different cycles. This approach, shifting the problem from the endowment (the latest technology) to the performance (obtained through the use of the most appropriate technologies), yet will allow to build ranking of cities that will incorporate, however, the specific nature and objectives of the different urban contexts.

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