Smart cities in Europe

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Abstract

Urban performance currently depends not only on the city's endowment of hard infrastructure ('physical capital'), but also, and increasingly so, on the availability and quality of knowledge communication and social infrastructure ('human and social capital'). The latter form of capital is decisive for urban competitiveness. Against this background, the concept of the 'smart city' has recently been introduced as a strategic device to encompass modern urban production factors in a common framework and, in particular, to highlight the importance of Information and Communication Technologies (ICTs) in the last 20 years for enhancing the competitive profile of a city.

The present paper aims to shed light on the often elusive definition of the concept of the 'smart city'. We provide a focussed and operational definition of this construct and present consistent evidence on the geography of smart cities in the EU27. Our statistical and graphical analyses exploit in depth, for the first time to our knowledge, the most recent version of the Urban Audit data set in order to analyse the factors determining the performance of smart cities.

We find that the presence of a creative class, the quality of and dedicated attention to the urban environment, the level of education, multimodal accessibility, and the use of ICTs for public administration are all positively correlated with urban wealth. This result prompts the formulation of a new strategic agenda for smart cities in Europe, in order to achieve sustainable urban development and a better urban landscape.

Keywords: smart city, urban development, human capital, transport infrastructure, ICTs

JEL classification codes: A13, L90, O18, R12

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Contents

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1. Introduction

What is the source of urban growth and of sustainable urban development? This question has received continuous attention from researchers and policy makers for many decades. Cities all over the world are in a state of flux and exhibit complex dynamics. As cities grow, planners devise "*complex systems to deal with food supplies on an international scale, water supplies over long distances and local waste disposal, urban traffic management systems and so on; (…) and the quality of all such urban inputs defines the quality of life of urban dwellers*" (The Science Museum 2004).

Notwithstanding the enormous formidable challenges and disadvantages associated with urban agglomerations, the world population has been steadily concentrating in cities. Figure 1 shows the percentage of US citizens living in cities (defined as agglomerations of more than 1,000 dwellers); a massive rise in this percentage took place, from 5.1 per cent in 1790 to more than 75 per cent of the US population being located in urban areas in the year 2000.

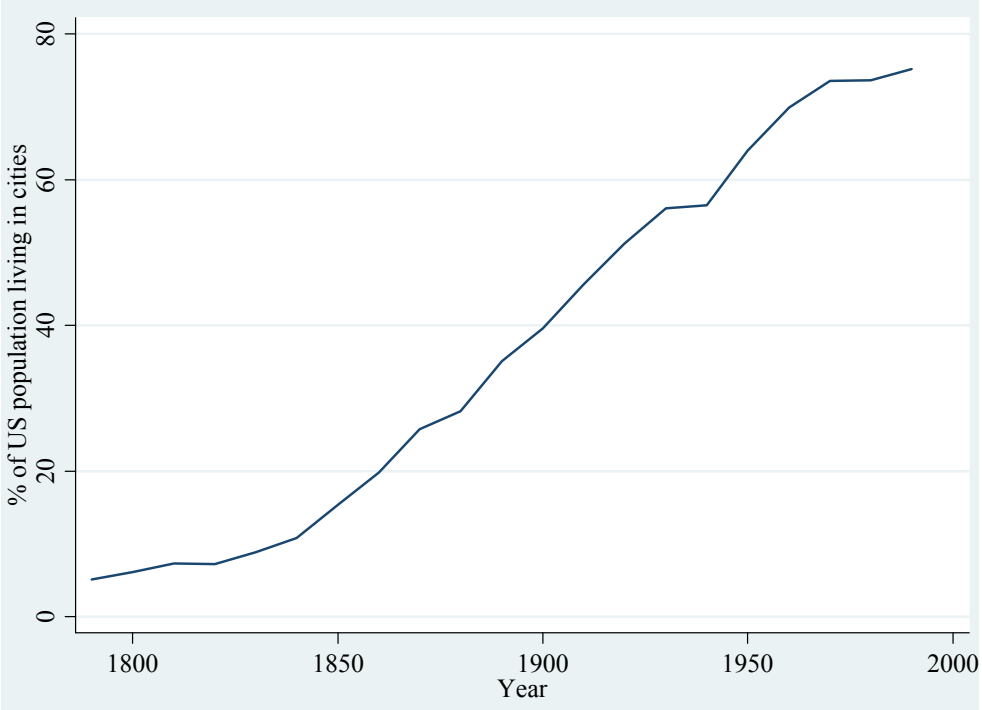

Figure 1 Percentage of US population living in urban areas, 1790-1990
Source: US Census

In addition, we also witness a substantial increase in the average size of urban areas. This has been made possible by a simultaneous upward shift in the urban technological frontier, so that a city could accommodate more inhabitants. Problems associated with urban agglomerations have usually been solved by means of creativity, human capital, cooperation (sometimes bargaining) among relevant stakeholders, and bright scientific ideas: in a nutshell, 'smart' solutions. The label 'smart city' should therefore point to clever solutions allowing modern cities to thrive, through quantitative

and qualitative improvement in productivity. However, when googling 'Smart city definition'[4], we discover that among the very first results we can name a communications provider, a US radio, an Edinburgh hostel, an initiative of the Amsterdam Innovation Engine, and so on; but no sign of a proper definition.

In the present paper we search for a clearer and focussed definition of the label 'smart city'. We next provide qualitative evidence on the correlations between the dimensions of our definition of smart cities and a measure of wealth, i.e. per capita GDP in Purchasing Power Parity (henceforth, PPP).[5] We will start with a brief literature review in the next section.

2. Literature review

The concept of the 'smart city' has been quite fashionable in the policy arena in recent years. Its main focus seems to be on the role of ICT infrastructure, although much research has also been carried out on the role of human capital/education, social and relational capital and environmental interest as important drivers of urban growth.

The European Union (EU), in particular, has devoted constant efforts to devising a strategy for achieving urban growth in a 'smart' sense for its metropolitan areas. Not only the EU, but also other international institutions and thinktanks believe in a wired, ICT-driven form of development. The Intelligent Community Forum produces, for instance, research on the local effects of the ICT revolution, which is now available worldwide. The OECD and EUROSTAT *Oslo Manual* (2005) stresses instead the role of innovation in ICT sectors and provides a toolkit to identify consistent indicators, thus shaping a sound framework of analysis for researchers on urban innovation. At a *meso*-regional level, we observe renewed attention for the role of soft communication infrastructure in determining economic performance.[6]

The availability and quality of the ICT infrastructure is not the only definition of a *smart* or *intelligent* city. Other definitions stress the role of human capital and education in urban development. Berry and Glaeser (2005) and Glaeser and Berry (2006) show, for example, that the most rapid urban growth rates have been achieved in cities where a high share of educated labour force is available. In particular Berry and Glaeser (2005) model the relation between human capital and urban development by assuming that innovation is driven by entrepreneurs who innovate in industries and products which require an increasingly more skilled labour force. As not all cities are equally successful in investing in human capital, the data show that an educated labour force – or, in Florida's jargon, the 'creative class' – is spatially clustering over time. This recognized tendency of cities to diverge in terms of human capital levels has attracted the attention of researchers and policy makers. It turns out that some cities, which were in the past better endowed with a skilled labour force, have managed to attract more skilled labour, whereas competing cities failed to do so. Policy makers, and in particular European ones, are most likely to attach a consistent weight to

[4] This Google search has been carried out on 8 April 2009.

[5] PPP methods make it possible to better represent spatial disparities in the level of prices, and, consequently, more accurately gauge the real spending power of economic agents.

[6] Del Bo and Florio (2008) offer a critical perspective on previous studies regarding the role of different forms of infrastructure in economic performance and provide empirical evidence on the contribution of single and aggregate measures of infrastructure on regional growth in the period 1995-2005.

spatial homogeneity; in these circumstances the progressive clusterization of urban human capital is then a major concern.

The label 'smart city' is still, in our opinion, quite a fuzzy concept. We can summarize the characteristics proper to a smart city that tend to be common to many of the previous findings as follows:[7]

1. The "*utilization of networked infrastructure to improve economic and political efficiency and enable social, cultural and urban development*"[8], where the term i*nfrastructure* indicates business services, housing, leisure and lifestyle services, and ICTs (mobile and fixed phones, satellite TVs, computer networks, e-commerce, internet services). This point brings to the forefront the idea of a wired city as the main development model and of connectivity as the source of growth.

2. An "*underlying emphasis on business-led urban development*". According to several critiques of the concept of the smart city, this idea of neo-liberal urban spaces, where business-friendly cities would aim to attract new businesses, would be misleading. However, although caveats on the potential risks associated with putting an excessive weight on economic values as the sole driver of urban development may be worth noting the data actually show that business-oriented cities are indeed among those with a satisfactory socio-economic performance.

3. A strong focus on the aim to achieve the social inclusion of various urban residents in public services (e.g. Southampton's smartcard).[9] This prompts researchers and policy makers to give attention to the crucial issue of equitable urban growth. In other words: To what extent do all social classes benefit from a technological impulse to their urban fabric?

4. A stress on the crucial role of high-tech and creative industries in long-run urban growth. This factor, along with 'soft infrastructure' ("*knowledge networks, voluntary organizations, crime-free environments, after dark entertainment economy*"), is the core of Richard Florida's research.[10] The basic idea in this case is that "*creative occupations are growing and firms now orient themselves to attract the creative. Employers now prod their hires onto greater bursts of inspiration. The urban lesson of Florida's book is that cities that want to succeed must aim at attracting the creative types who are, Florida argues, the wave of the future*" (Glaeser 2005). The role of creative cultures in cities is also critically summarized in Nijkamp (2008), where creative capital co-determines, fosters and reinforces trends of skilled migration. While the presence of a creative and skilled workforce does not guarantee urban performance, in a knowledge-intensive, and increasingly, globalized economy, these factors will determine increasingly the success of cities.

5. Profound attention to the role of social and relational capital in urban development. A smart city will be a city whose community has learned to learn, adapt and innovate (Coe et al 2001). People need to be able to use the technology in order to benefit from it: this refers to the

[7] This section summarizes and further elaborates the main points in Hollands (2008), adding a critical review of the literature on urban growth from an economist's perspective.
[8] The use of italics in this list indicates a citation from Hollands (2008). On this first point, see also Komninos (2002).
[9] See Southampton City Council 2006.
[10] See, e.g., Florida (2002).

absorptive capacity literature.[11] When social and relational issues are not properly taken into account, social polarization may arise as a result. This last issue is also linked to economic, spatial and cultural polarization. It should be noted, however, that some research actually argues the contrary. Poelhekke (2006), for example, shows that the concentration of high skilled workers is conducive to urban growth, irrespective of the polarization effects that this process may generate at a *meso-* (for example, regional) level. The debate on the possible class inequality effects of policies oriented towards creating smart cities is, however, still not resolved.

6. Finally, social and environmental sustainability as a major strategic component of smart cities. In a world where resources are scarce, and where cities are increasingly basing their development and wealth on tourism and natural resources, their exploitation must guarantee the safe and renewable use of natural heritage. This last point is linked to the third item, because the wise balance of growth-enhancing measures, on the one hand, and the protection of weak links, on the other, is a cornerstone for sustainable urban development.

Items 5 and 6 are for us the most interesting and promising ones, from both a research and a policy perspective. In the next sections we provide quantitative and analytical evidence on the role of the creative class and human capital in sustainable urban development, arguing that it is indeed the mix of these two dimensions that determine the very notion of a 'smart' city. The relational capital side of the story is not evaluated in the present paper, but this will be the subject of further research in future studies.

Along with the previously mentioned critical points, additional critiques have been advanced to question the concept of a *smart* or *intelligent* city. Hollands (2008) provides a thorough treatment of the main arguments against the superficial use of this concept in the policy arena. His main points are the following:

- The focus of the concept of *smart city* may lead to an underestimation of the possible negative effects of the development of the new technological and networked infrastructures needed for a city to be smart (on this topic, see also Graham and Marvin 2001);

- This bias in strategic interest may lead to ignoring alternative avenues of promising urban development;

- Among these possible development patterns, policy makers would better consider those that depend not only on a business-led model. As a globalized business model is based on capital mobility, following a business-oriented model may result in a losing long term strategy: *"The 'spatial fix' inevitably means that mobile capital can often 'write its own deals' to come to town, only to move on when it receives a better deal elsewhere. This is no less true for the smart city than it was for the industrial, manufacturing city".*[12]

[11]This concept has been applied to different economic relations at different levels of spatial aggregation. The basic reference is Cohen and Levinthal (1990); Abreu et al. (2008) bridges the idea from a micro-, firm level to a more aggregated, meso-level; finally, Caragliu and Nijkamp (2008) test the role of regional absorptive capacity in inducing spatial knowledge spillovers.

[12] Hollands (2008), p. 314.

Our paper will now provide some quantitative evidence on these points, supported by spatial statistics, maps and graphical evidence on each of the points that the literature on smart cities has put forward, in order to explore and identify statistical correlations with socio-economic urban performance.

3. An operational definition of the 'smart city'

A narrow definition of a much-used concept may help in understanding the scope of the present paper. Although several different definitions of *smart city* have been given in the past, most of them focus on the role of communication infrastructure. However, this bias reflects the time period when the smart city label gained interest, viz. the early 1990s, when the ICTs first reached a wide audience in European countries. Hence, in our opinion, the stress on the internet as 'the' smart city identifier no longer suffices.

A recent and interesting project conducted by the Centre of Regional Science at the Vienna University of Technology identifies six main 'axes' (dimensions) along which a ranking of 70 European middle size cities can be made. These axes are: a smart economy; smart mobility; a smart environment; smart people; smart living; and, finally, smart governance. These six axes connect with traditional regional and neoclassical theories of urban growth and development. In particular, the axes are based – respectively – on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of societies in cities. We believe this offers a solid background for our theoretical framework, and therefore we base our definition on these six axes.

We believe a city to be 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.*

4. Quantitative and graphical evidence on European smart cities

In this section we will present graphical and quantitative evidence on the relative performance and rankings of European cities with respect to measures reflecting some of the definitions of a smart city given in the literature. The data source is the Urban Audit data set in its latest wave (2003-2006).[13] Cities that were surveyed in the latest available wave are depicted in Map 1.

[13] The Urban Audit entails a collection of comparable statistics and indicators for European cities; it contains data for over 250 indicators across the following domains:

- Demography;
- Social aspects;
- Economic aspects;
- Civic involvement;
- Training and education;
- Environment;
- Travel and transport;
- Information society;
- Culture and recreation.

Map 1: Cities in the 2003-2006 Urban Audit survey

We now present a set of charts which show partial correlations between urban growth determinants and our measure of economic output, which is per capita GDP in purchasing power standards (PPS) in 2004 (the latest data available in the Urban Audit data set).

The set of all partial correlations among the variables we use to measure the "smartness" of European cities can be found in Table 1, with corresponding p-values in parentheses. It is evident that most of the variables which we deem as capable of both co-determining long-run urban performance and characterizing a thorough definition of *smart* city, tend to be positively associated with our measure of urban wealth (we chose per capita GDP in PPS in 2004 in order to avoid the problem of size effects and to take into account price differentials across countries, which might be particularly different among EU15 and New Member State (NMS) cities).[14] Throughout this section, on the map as well as in our charts, we indicate the name of the city associated with each observation. We believe this to be a useful tool of analysis for both researchers as well as policymakers, to identify intriguing spatial issues in the Urban Audit data set, the possible presence

[14] An interesting but puzzling result arises for the relationship between the level of education of people living in our sample and their average individual income; this issue will be further analysed later in this section.

of country effects, and more in general to allow the reader to identify the locational patterns of our *smart* city measures.

Table 1 Partial correlations between the sic indicators of Smart Cities

	Per capita GDP in PPS	Employment in the entertainment industry	Multimodal accessbiility	Length of public transport network	e-Government	Human capital
Per capita GDP in PPS	1					
Employment in the entertainment industry	0.215	1				
	(0.1258)					
Multimodal accessibility	0.7049	-0.0059	1			
	0	(0.9553)				
Length of public transport network	0.3104	0.2874	0.0919	1		
	(0.0043)	(0.0302)	(0.312)			
e-Government	0.1418	-0.0254	0.141	-0.0339	1	
	(0.1751)	(0.8385)	(0.1004)	(0.7417)		
Human capital	-0.1361	-0.0983	0.0833	-0.0741	0.0665	1
	(0.265)	(0.3649)	(0.3616)	(0.5946)	(0.5733)	

Note: p-values are in parentheses

Figure 2 offers partial support for Richard Florida's arguments on the role of the 'creative class' in determining long-run urban performance. Positive correlations between the share of people employed in a 'creative' industry[15], and in particular in the 'super-creative core'[16], are found in US cities and states. Here, we measure these effects with the share of the labour force in European cities in the culture and entertainment industry, and find indeed that the two measures show a positive and significant correlation (the correlation coefficient equals .2150 with a p-value of .1258).

In the urban economics literature, Florida's view has not been exempt from criticism.[17] In the opinion of several economists, the argument that the creative professions would drive urban performance is flawed, and it would only be a proxy for the role of the 'hard' measurable stock of human capital (i.e. technical professions and total years of schooling) on urban growth. Shapiro (2008) provides an excellent and convincing bridge between the two views. In his paper he proves with careful econometric estimations that human capital in cities contributes both directly to urban growth (measured by the growth of population, wages and two land rent measures) through productivity gains and indirectly through the increase in urban amenities, which in turn may foster

[15] See Florida (2002, 2009).

[16] In Florida (2002) the 'creative class' is defined as the merger of two Standard Occupational Classification System codes within the US labour force, viz.:

- A *super-creative core* with those employed in science, engineering, education, computer programming, research, and with arts, design, and media workers making a small subset. Those belonging to this group are considered to *"fully engage in the creative process"* (Florida, 2002, p.69);
- *Creative professionals* with those employed in healthcare, business and finance, the legal sector, and education.

[17] See, for example, Glaeser (2005).

the process of attraction of the creative class. Although the productivity effects are still the largest, according to Shapiro's estimates the amenities effects would account for as much as 20 to 30 per cent of total human capital effects on urban growth.[18]

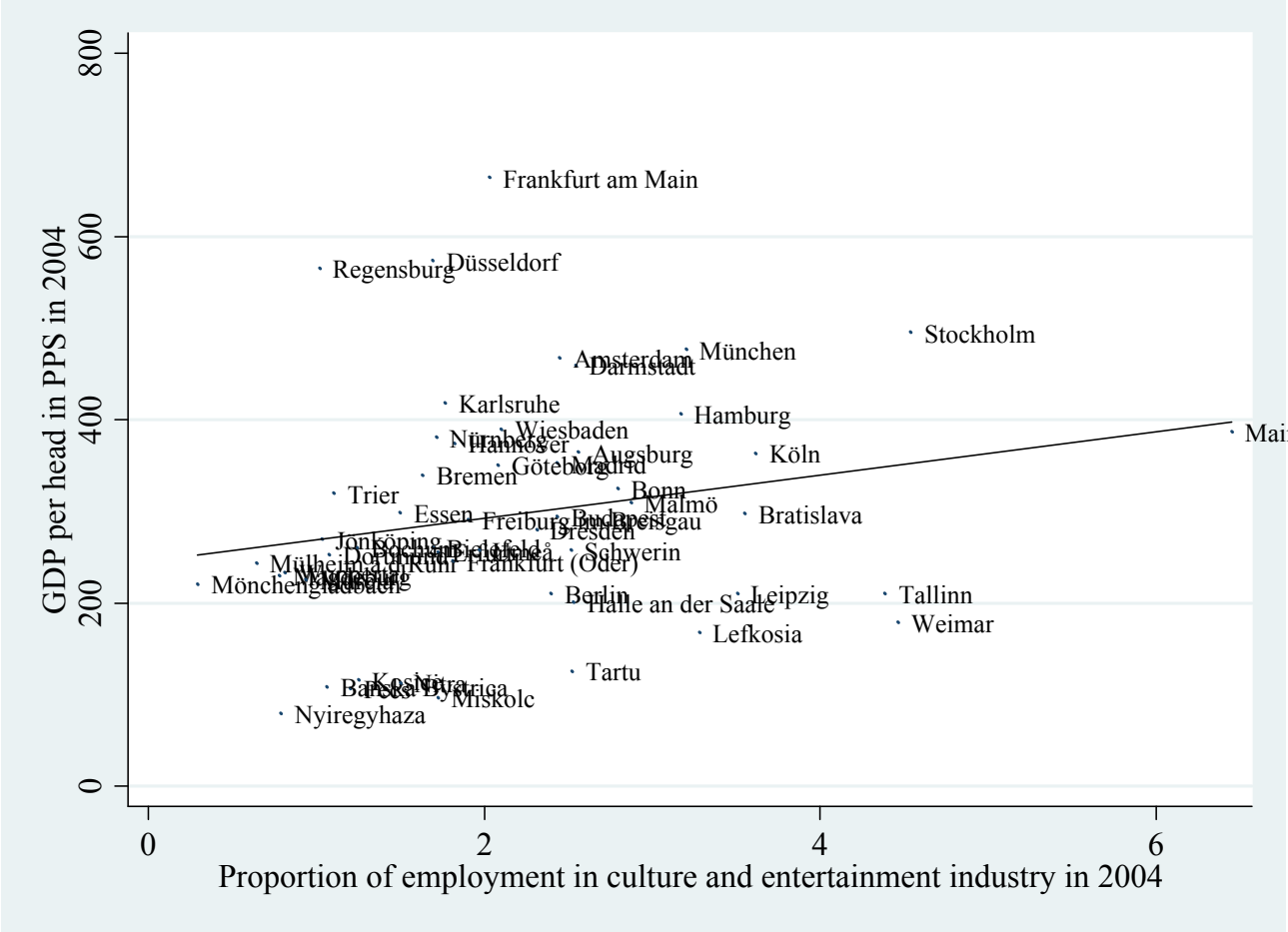

Figure 2 Creative class and wealth in 2004

A second positive (and extremely significant) correlation appears to exist between multimodal accessibility and per capita GDP (Figure 3). In this chart, the accessibility indicator, calculated as a weighted average of the ease with which a city can be reached with a combined set of available transportation modes (i.e. rail, road, sea or plane), also represents a measure for the market potential available to and from the city itself. Therefore, a better endowment of transportation means might be conducive to wealth and growth, this last statement being in line with the New Economic Geography's theoretical expectations.[19]

[18] The direct causal mechanism will be graphically analysed later in this section.
[19] For the role of the market potential in driving economic performance in the New Economic Geography literature, we refer to Redding and Sturm (2008), amongst others.

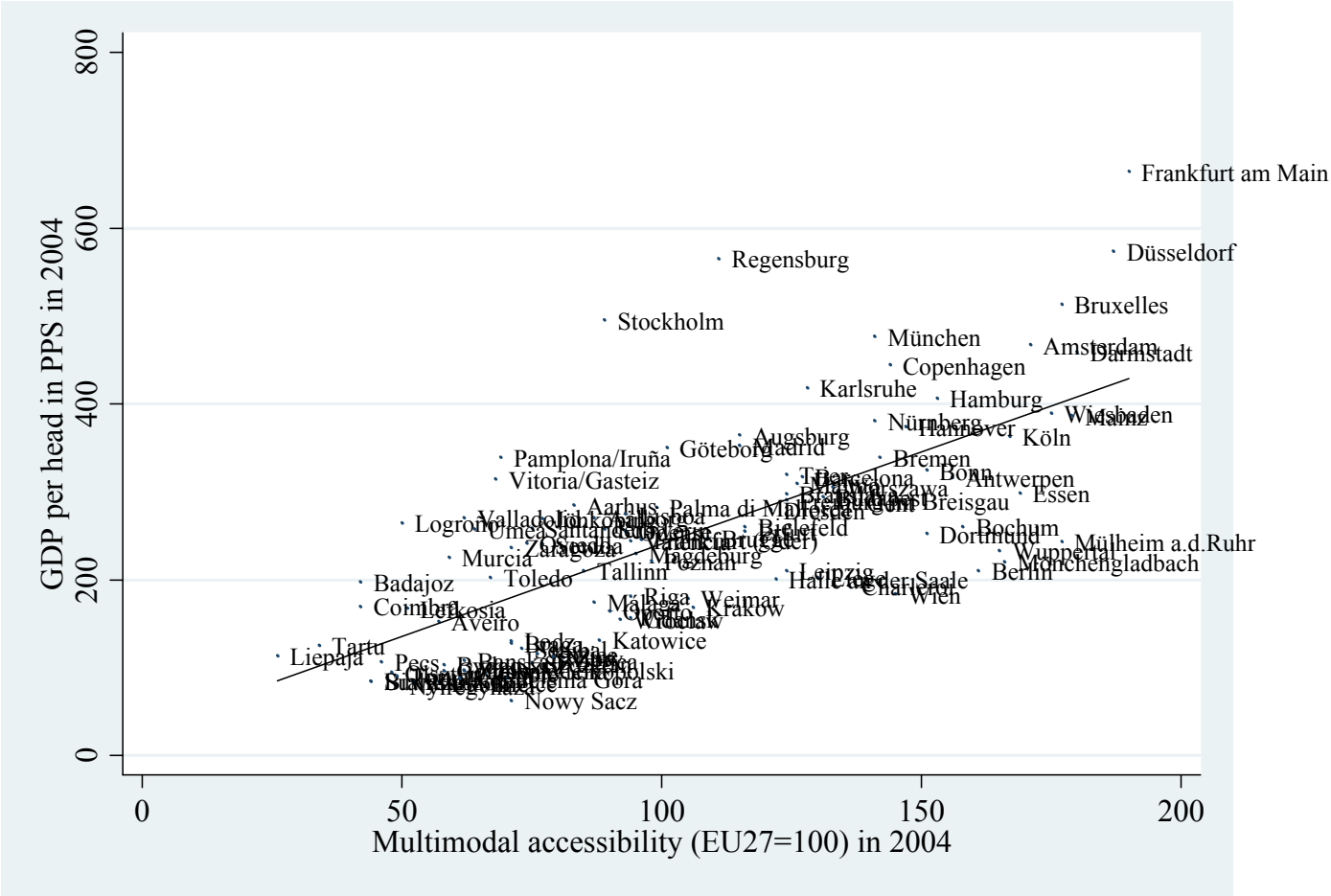

Figure 3 Accessibility and wealth in 2004

Figure 4 shows instead the relationship between the availability of public transportation (normalized by the city area) and the level of wealth, measured as before with per capita GDP in PPS. The relationship is strongly positive; the city of Stockholm has been excluded from the original dataset as it behaves as an outlier, with an outstandingly high density of public transportation. With the inclusion of Stockholm the interpolation line would become even steeper. It is quite evident that an efficient net of public transportation is associated with high levels of wealth. Although the direction of causality in this relation may go both ways, it seems reasonable to think that a dense public transportation network may help to reverse the negative effects of urban density, thus at least partly releasing the pressure this exerts on the urban landscape and reducing the costs associated with congestion.

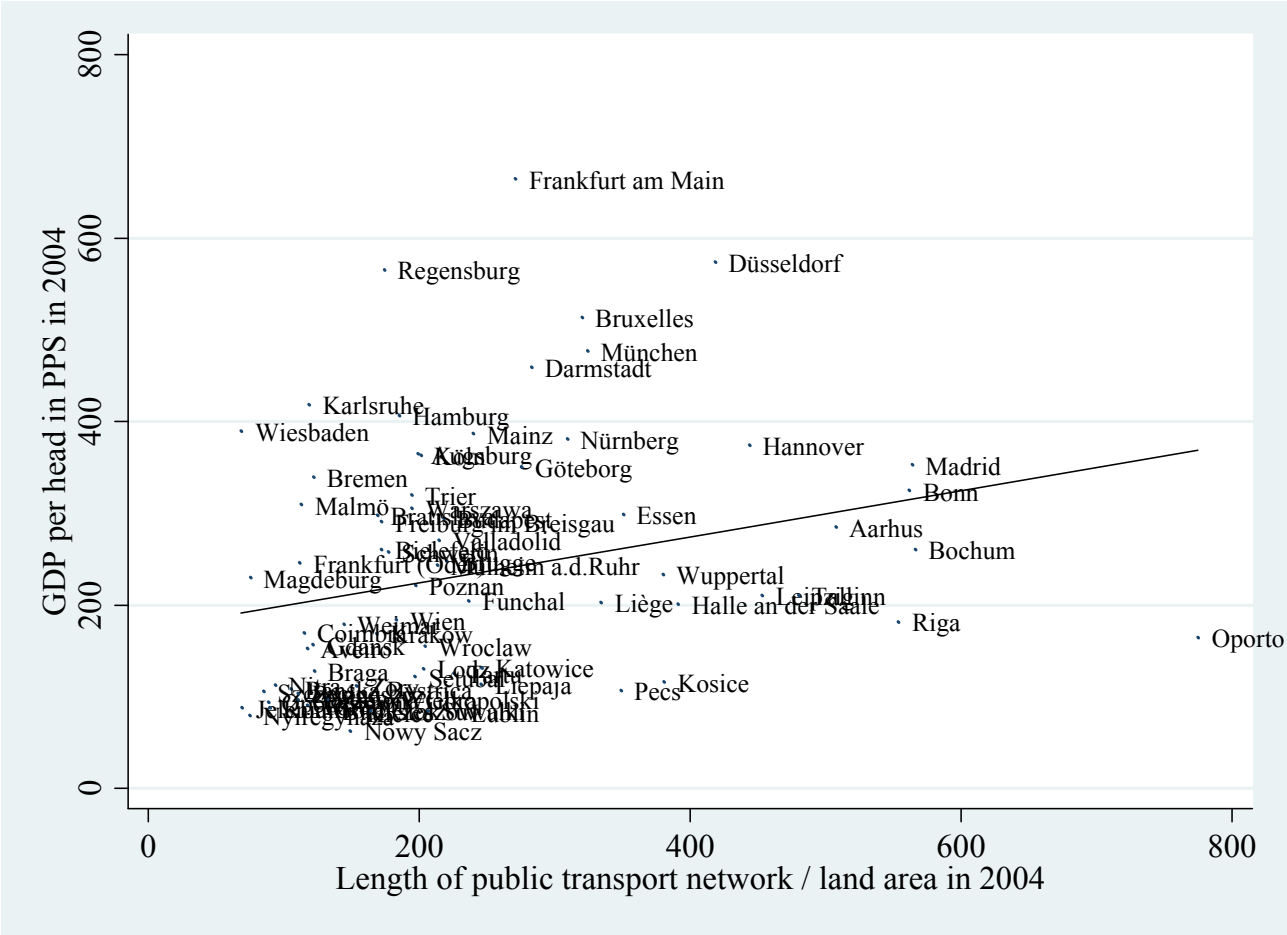

Figure 4 Public transport and wealth

A slightly less significant and less steep association can be found between the level of GDP and a measure of e-government. The Urban Audit data set yields both the absolute number of government forms that can be downloaded from the website of the municipal authority, as well as the number of administrative forms which can be submitted electronically. As this last series has slightly more observations, and is, in our opinion, a better measure of the real chance for citizens to interact with the urban Public Administration via the net, we represent this in Figure 5. The city of Krakow is in this case excluded as an outlier (in terms of number of forms that can be submitted online). The relationship does not change when the e-government measure is normalized by population or labour force (although this operation slightly changes the relative ranking of the cities in our sample).

Although cities with a high level of per capita GDP also tend to devote more attention to 'smart', e-government solutions, it is interesting to observe that some noticeable exceptions characterize this analysis. Some cities in peripheral countries (Krakow in Poland, Zaragoza in Spain, Ponto Delgada in Portugal) have also devised a wide set of forms that citizens can submit online, thus reducing travel and commuting costs, and costs associated with the management of multi-task public administration bodies.

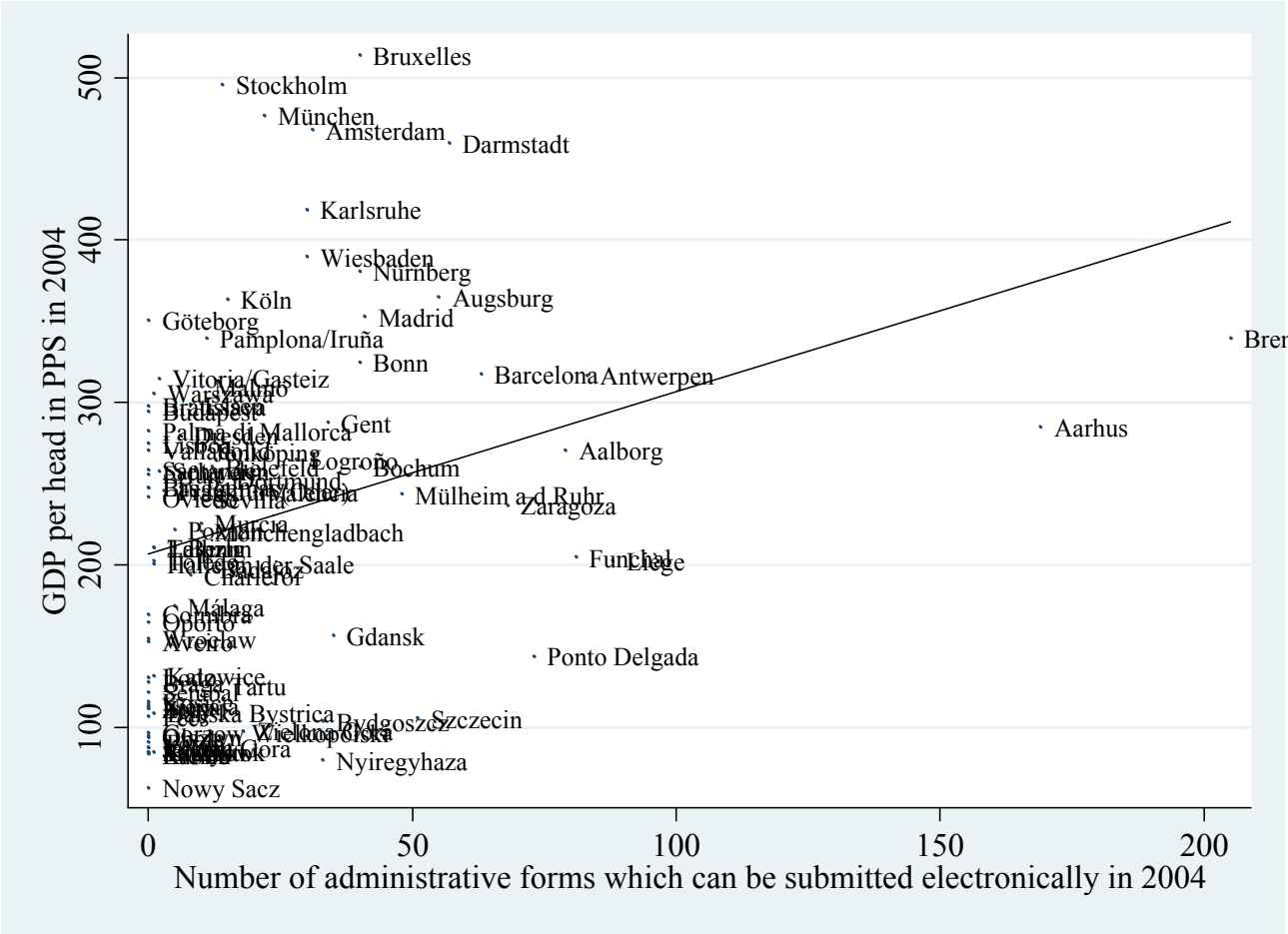

Figure 5 e-Government and wealth

Finally, Figure 6 shows the relationship between the stock of human capital and the level of urban wealth. According to neoclassical theories (Lucas 1988, Arrow 1962, Mankiw et al. 1992), human capital levels are good predictors of subsequent economic performance. As Table 1 shows, in our sample this positive relationship has, nevertheless, more complex characteristics. The correlation coefficient between our measure of human capital, i.e. the share of the labour force qualified at ISCED levels 3 and 4,[20] and the level of GDP is negative (although not significant at any statistical confidence level). Does this imply that more education is associated with poorer economic conditions? If we look at Figure 5 it seems clear that the correct fit of this relationship is through a quadratic interpolation. After an appropriate (quadratic) term has been taken into account, the linear correlation between human capital and GDP is positive and significant at the 1 per cent level.[21]

The interpretation of this finding is, however, more difficult. By inspecting Figure 5 it is possible to identify some observations on the right-hand side of the chart as cities in the new Member States of the EU. As a legacy of the communist period, when levels of education were deliberately held high, labour forces in those countries may still own a large stock of human capital, albeit that overall

[20] "*The International Standard Classification of Education (ISCED) was designed by UNESCO in the early 1970's to serve 'as an instrument suitable for assembling, compiling and presenting statistics of education both within individual countries and internationally'. It was approved by the International Conference on Education (Geneva, 1975), and was subsequently endorsed by UNESCO's General Conference when it adopted the Revised Recommendation concerning the International Standardization of Educational Statistics at its twentieth session (Paris, 1978)*" (from unesco.org).

[21] Evidence of this last finding is available from the authors upon request.

levels of individual wealth may not yet match those of the old Member States. In this case, therefore, the depicted relationship may actually represent an off-saddle growth path portrait of the real human capital-urban growth equation.[22]

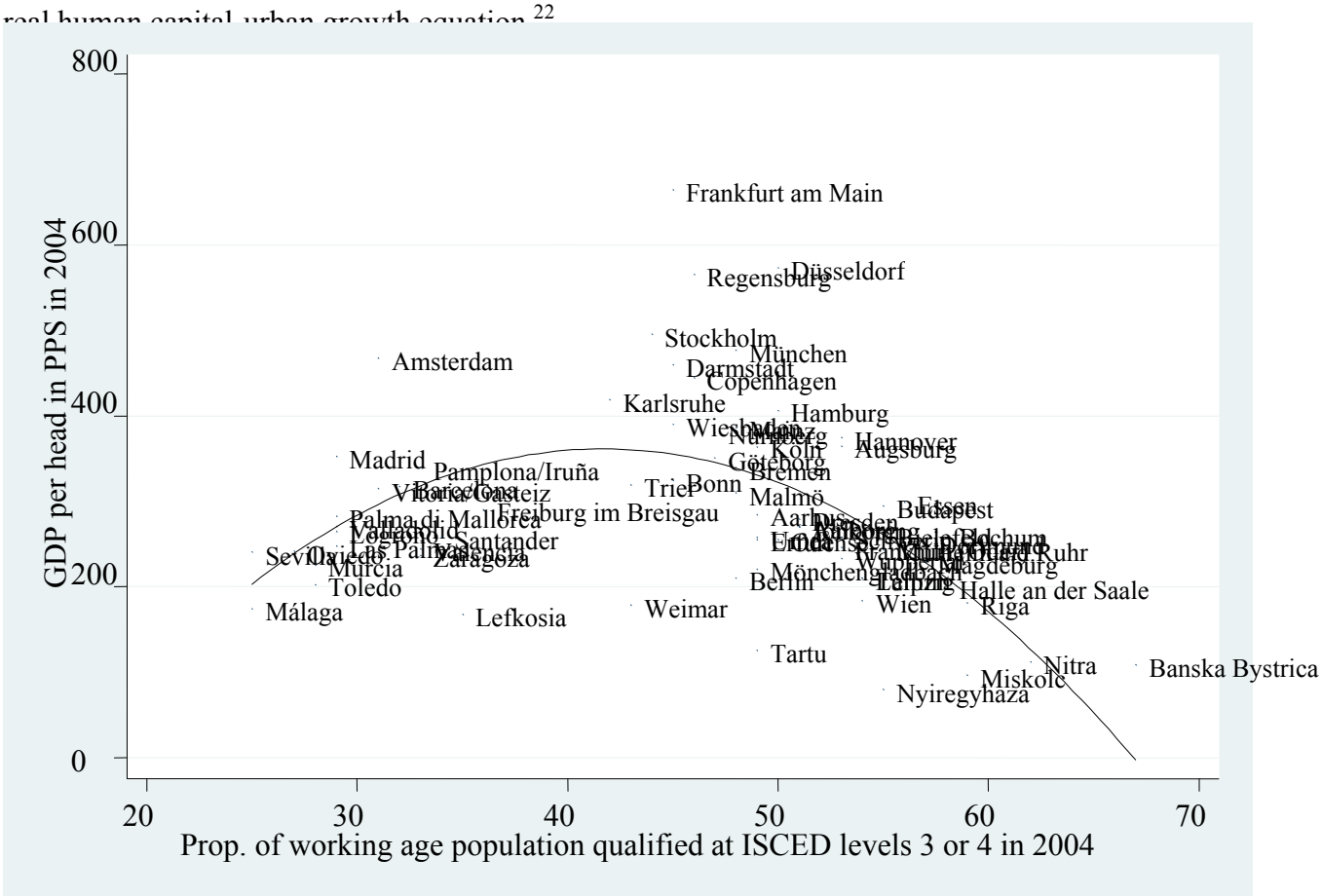

Figure 6 Human capital and wealth

A second key to interpret the puzzle may be by reconnecting our study to Mayer (2007). She analyses the different ways in which cities and regions can set up a high-technology cluster even without the presence of a sound research-oriented university, whilst also criticizing the opposite side of the story, viz. the idea that academic research centres are a necessary and sufficient condition for achieving high-tech oriented urban development. Therefore, cities in new Member States may still fail to provide a sound connection between academic research institutes and the real economy, thus failing to attract the human capital-rich workers who raise productivity and wealth.

5. Conclusions and policy implications

In this paper, we have presented an overview of the concept of the 'smart city', with a critical review of the previous economics and planning approaches to this concept. We then presented a narrower definition of the concept of the smart city, and reviewed some quantitative and graphical

[22] Indirect evidence to support this guess comes from splitting the sample into countries that in the 1980s were liberal or 'capitalist' in Europe and those which belonged to COMECON, and then fitting the data with a linear trend; the latter turns out to be positive and significant for the first of these two subsamples and negative and significant for the second .

evidence on the correlations of some of the main determinants of economic performance and the most important measure of urban success, viz. per capita wealth.

Data from the 2004 Urban Audit data set show consistent evidence of a positive association between urban wealth and the presence of a vast number of creative professionals, a high score in a multimodal accessibility indicator, the quality of urban transportation networks, the diffusion of ICTs (most noticeably in the e-government industry), and, finally, the quality of human capital. These positive associations clearly define a policy agenda for smart cities, although clarity does not necessarily imply ease of implementation.

All variables shown to be positively associated with urban growth can be conceived of as stocks of capital; they are accumulated over time and are subject to decay processes. Hence, educating people is on average successful only when investment in education is carried out over a long period with a stable flow of resources; transportation networks must be constantly updated to keep up with other fast-growing cities, in order to keep attracting people and ideas; the fast pace of innovation in the ICT industry calls for a continuous and deep restructuring and rethinking of the communication infrastructure, to prevent European cities from losing ground to global competitors.

This continuous challenge, the 'endless frontier' to quote Vannevar Bush's words on scientific research (Bush 1945), is the only way to ensure a sustainable path of development for cities, whilst at the same time guaranteeing that cities will maintain their crucial role as the cradle of ideas and freedom.

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