Smart Cities, Metrics and the Future Internet-based Governance of Urban and Regional innovations

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Abstract

This paper summarizes the outcomes of a literature review on smart cities and goes on to provide an overview of the critical insights it offers. By-passing populist academic readings of the subject and offering a critique of the Smart City Ranking, Future Internet development and Triple Helix models, it argues the insights this review of the literature offers get beyond the state-of-the-art. That is to say, beyond the status of Smart City Ranking and articulations of the Future Internet development thesis, by overcoming the criticisms which mode 2 and 3 accounts of knowledge production otherwise levy at the Triple Helix model. Which such accounts of knowledge production otherwise levy at the Triple Helix model, but the critical synthesis that is set out in this paper's account of smart cities manages to overcome. Manages to overcome by rendering the metrics of a future internet-based governance discernable as measures of wealth created from the intellectual capital of these technologies. As measures of the wealth created from the intellectual capital of these technologies and application of them as urban and regional innovations.

Keywords: smart cities, triple helix model, governance, performance

JEL: O18, 033, 043, R10, R50

Introduction

The state-of-the-art on smart cities has been captured by Deakin (2010, 2011, 2012, 2013, 2014, 2015) as a retrospective on the research undertaken, reported on and disseminated as part of the SmartCities project.[1] This extensive review of the literature identifies three emerging accounts of

[1] http://www.smartcities.info/

smart cities. Listing them chronologically, the emerging accounts are of Smart City Rankings, Future Internet developments and the Triple Helix model of smart cities. All claim to capture something significant about the development of smart cities and offer a critically insightful account of their performance.

What follows summarizes the findings of this literature review and goes on to provide an overview of the critical insights that it offers into the development of smart cities. It then turns attention to the metrics of the future internet-based governance advanced to regulate the growth of smart cities by advocates of the Triple Helix model. This is followed by an account of how the intellectual capital, wealth creation and regulatory standards of this governance model can be assembled to measure the performances of smart cities as urban and regional innovations.

These critical insights make it possible to go beyond the "potential of what smart cities can be" (Townsend, 2013: 17), or they "can never become" (Greenfield, 2013: 10) and capture the reality of what they are with respect to the metrics cities are developing to be smart in measuring such performances. This is because these insights are based, not on scholarly accounts of smart cities, but on the research undertaken to support such urban and regional innovations and generally acknowledged to be the standard-bearers of what is known about the subject. That research, it might be added, which is underpinned not by opinion, but by that normal process of peer review, which supports the publication of scholarly journals assumed to be of scientific and technical value.

Literature review

For Giffinger et al. (2008), Smart City Rankings offer cities the means to 'outsmart' each other in marketing their attributes. In this examination of smart cities, standard city ranking procedures are recast by prefixing the word 'smart' to terms like 'people', 'living', 'mobility', 'governance', 'environment' and 'economy' and assembling a set of indicators to approximate their respective factor performances. Such factor performances include hard and soft attributes, such as innovative spirit,

entrepreneurialism, economic image and trademarks, creativity, cosmopolitism and open mindedness. Hard and soft attributes, Giffinger et al. (2008: 4) suggest, offer cities a measure of "smartness" because they: "imply the implicit or explicit ambition/intention to improve performance" (ibid).

Schaffers et al. (2011) and Komninos et al. (2013) set out the Future Internet development thesis. As Schaffers et al. (2011) state, the first task that cities must address in becoming smart is to develop infrastructures able to support the application of Web2.0 services. These include the following:

- the development of broadband infrastructures, combining cable, optical fiber and wireless networks, with bandwidths offering high levels of connectivity to organizations, businesses and citizens within cities;
- an enrichment of the physical space and digital infrastructures of cities with embedded systems, smart devices, sensors, and actuators, offering real-time data management, alerts and information processing.

As Schaffers et al. (2011) stress, the creation of applications enabling data collection and processing, web-based collaboration and collective intelligence in cloud computing (compatible with the emerging Internet of Things) is the first task to consider. This is because, for Schaffers et al. (2011), these are the only technologies that can assure economies of scale in digital infrastructure provision and the standardization of applications in turnkey solutions. The second task they identify is that of initiating large-scale participatory innovation processes and which relate to the creation of applications able to improve every sector of activity, city cluster and infrastructure.

As Schaffers et al. point out, in creating the infrastructures of this rich eco-system and initiating large-scale participatory innovation, two different layers of collaboration come into play. The first layer relates to collaboration within the innovation process, which generates interaction between research, technology and application development. The second layer concerns collaboration at the territorial level, aimed at strengthening urban and regional innovation.

The basis for the Triple Helix model is Leydesdorff and Deakin's (2011) paper on smart cities. This brings to light how the Triple Helix model of smart cities provides the opportunity to study the knowledge economy in terms of the social capital, cultural attributes and environmental qualities underpinning the development of digital infrastructures and supporting the urban and regional innovation on which they stand (see also Deakin 2012; Deakin and Leydesdorff, 2013).

In this schema, cities are densities in networks among at least three relevant dynamics: that is, the universe of intellectual capital, industry of wealth creation and the participatory governance of the democratic system, which forms the rule of law. The effects of these interactions in turn generate spaces in which information and communication technologies (ICTs) create the notion of smart cities and exploit the opportunities that Future Internet developments offer not only to generate intellectual capital, but for these technologies to also create wealth, as much from the social capital, cultural attributes and environmental qualities of these digital infrastructures as from any economic value.

While the specific combination of knowledge products needed for these sub-dynamics to align with one another is an unknown requirement, it is the reflexive instability of the intellectual capital and wealth creation wrapped up in the social capital, cultural attributes and environmental qualities of these digital infrastructures which is of particular interest. This is because what such a co-evolutionary mechanism offers is the prospect of cities becoming smart in turning the reflexive instability of these ICTs to their advantage: that is, by exploiting the opportunity which Future Internet developments offer to not only generate intellectual capital, but for these technologies to also create wealth from the social capital, cultural attributes and environmental qualities of the digital infrastructures that allow cities to be smart in governing the way in which communities, businesses and citizens alike can participate in such urban an regional innovations.

Overview

This overview of the state-of-the-art suggests the following:

- each of the three accounts accepts the need for some form of Smart City Ranking;
- Future Internet developments account for the digital infrastructures which smart cities assemble the means for and participate in the application of;
- the Triple Helix model sees the participatory governance of the wealth created from the intellectual capital of these technologies as key to the development of the Future Internet and application of the digital infrastructures smart cities assemble as urban and regional innovations.

This offers a critical insight into the three accounts of smart cities: that is, while each of them accepts the need for some form of Smart City Ranking and the Future Internet development thesis assembles the means to participate in the intellectual capital these technologies generate, it is the Triple Helix model, which sees the governance of the wealth created as key to the application of them as urban and regional innovations (Deakin, (2014, 2015).

This is why what follows chooses to progress this overview of the literature on smart cities by way of a critical synthesis and though a Triple Helix inspired model of *smart cities* founded on the *metrics of a future internet-based governance*. In particular, founded on the metrics of that future internet-based governance which in turn stands as a platform to account for the wealth created by the intellectual capital of these technologies and application of them as *urban and regional innovations.*

Critical synthesis

As a critical synthesis of the Smart City Ranking, Future Internet thesis and Triple Helix model of smart cities, the metrics of this future internet-based governance manage to overcome the main criticism Cook (2005) aims at the Triple-Helix model: in particular, that criticism, which suggests the

intellectual capital of the technologies it stands on offers little more than a 'mode 2' inspired meta-narrative on wealth creation, lacking the metrics to measure the performance of cities (smart or otherwise) as the knowledge economy of an urban and regional innovation. While sympathetic to this criticism, the metrics of the future internet-based governance set out in this paper serve to offer an index of those technologies that are integral to the Triple Helix model of smart cities and urban and regional innovation on which this stands. It is for this reason, the critical synthesis set out in this paper also resists the temptation to break with the mode 2 critique of the Triple Helix as part of any search for what Carayannis and Campbell (2012) refer to as the social ecology of a 'mode 3' knowledge production: that social ecology in which it is not either the intellectual capital that technologies generate, or wealth this creates, but the media of the creative sector whose institutions are considered as key to the application of them as urban and regional innovations. For while Cook's (2005) critique of the Triple Helix is methodological, to do with the scale of analysis and absence of any metrics to measure the intellectual capital of the technologies it generates, Carayannis and Campbell's (2012) criticism relates to the absence of key stakeholder communities whose wealth creation should be represented in any metrics compiled to measure the application of them as urban and regional innovations.

What follows suggests that such criticisms are not fundamental enough to reveal some division between the knowledge economy of civil society, or structural in terms of any antagonism in the body of knowledge this produces, but mainly methodological and technical, lacking in substance and insufficiently extensive to legitimate either a rejection (Cook) or radical reconstruction of the Triple Helix (Carayannis and Campbell). Instead, the paper suggests these criticisms provide the opportunity to do the opposite and intensify the Triple Helix model's search for the missing metrics, each of them seen a pivotal to any claims made about the future internet-based governance of smart cities. In particular, pivotal to any claims made about a future internet-based governance of that wealth which is created from the intellectual capital of these technologies and application of them as urban and regional

innovations stakeholder communities can stand by as performance measurements.

The metrics

The metrics for this future internet-based governance are drawn from the Triple Helix model of intellectual capital advanced by Lombardi et al. (2012) Lombardi and Giordano (2012] and Kourtit et al. (2013) and as a process of wealth creation. This Triple Helix model serves to do what Lazaroiu and Roscia (2012) ask of these technologies, i.e. reach beyond the block box of Smart City Ranking and the collaborative logic of Future Internet-based developments. It does this by allowing those cities pioneering the development of Future Internet-based technologies to be smart in underpinning the digital infrastructures supporting all of this as the data management systems of an urban and regional innovation. In that sense, do what the likes of Lazaroiu and Roscia (2012) and Caragliu et al. (2013a, 2013b) all ask of smart cities: be successful in sustaining the types of positive associations which Future Internet developments assume them to be the harbingers of. In particular, harbingers of a development able to sustain these positive associations by pioneering a deep restructuring of the ICT sector that allows the Future Internet to extend beyond the digital infrastructures of data management systems, by cutting deep into the energy, water and waste sectors, which the governance of smart cities has previously been excluded from.

This deep restructuring i.e. as the digital infrastructures of data management systems designed to optimize the ICT, energy, water and waste sectors, is something Lombardi et al. (2012) draw particular attention. It is a matter that Hirst et al. (2012) also highlight as of growing significance for the European Commission's (ECs) Smart, Sustainable and Inclusive Growth Strategy and translation of this into the design and implementation of the Smart Cities and Communities Programme.[2]

[2] http://eu-smartcities.eu/content/fp7-smart-cities-and-communities-call-proposals-now-open

Hirst et al. (2012) explore the metrics of the ICT, energy, water and waste infrastructures. They offer a principal component-based grid for modelling smart cities as a set of performance measurements. This is set out in Figure 1 and illustrates the findings of the work undertaken to capture instances of where cities have been smart in underpinning the deep restructuring of the ICT and energy sectors: in particular, instances of where cities have been smart in underpinning the digital infrastructures and supporting the contribution made by the ICT and energy sectors to Europe's Smart, Sustainable and Inclusive Growth Strategy[3].

This configuration identifies the pioneers of Europe's Smart, Sustainable and Inclusive Growth Strategy to be the cities of Manchester, Amsterdam, Malmö and Barcelona (see Figure 1). It also identifies how these smart cities have begun to construct sustainable and inclusive growth strategies around innovation in the digital infrastructures of the data management systems promoted by the ICT and energy sectors. This configuration in turn highlights the infrastructural components of the growth strategy: in particular, the data management systems, renewable energy, smart buildings and equivalent transport components of this innovation. It also goes some way to identify the principal legacy systems of smart city development: namely the ICT and energy sectors and modulation of their growth as a broadband of digital infrastructures, data management systems, renewable energy, smart buildings and related transport applications.

With the ICT sector, attention focuses on the smart growth of the first two modulations (digital infrastructures and data management systems), whereas with the energy sector, weight is placed on the sustainable and inclusive growth of the renewable energy, smart buildings and transportation. This also serves to illustrate the top-level issues that get bottomed out within the legacy systems to which they relate. With the ICT sector, the drivers of smart growth are issues such as high-speed broadband, data collection and storage; issues that bottom-out in the energy sector as the smart grids and meters of renewable energies installed in buildings which support the

[3] http://ec.europa.eu/europe2020/index_en.htm

Internet of Things (IoT): that is, as the combined heat and power and efficiency measures which underpin the sustainable and inclusive growth strategy and support this Smart Cities and Communities Programme.

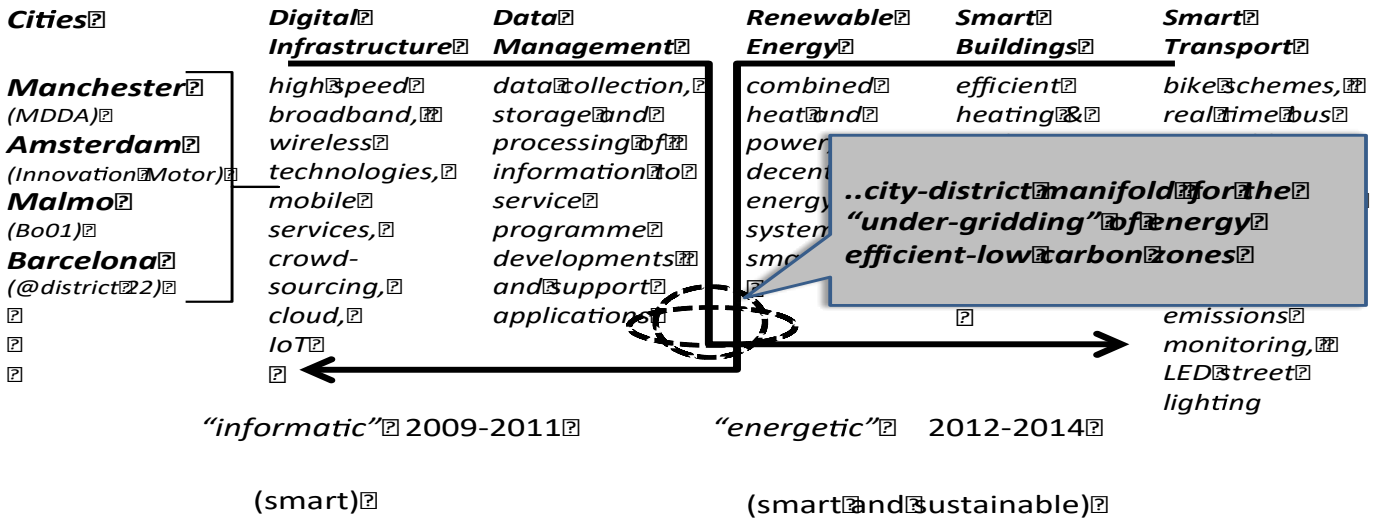

Figure 1: A principal component-based analysis of smart city developments
Source: Adapted from Hirst et al. (2012), Deakin et al. (2014) and Dakin and Reid (2016)

Figure 1 also serves to highlight where the integration of these legacy systems (shown as the informatics and energetics of smart cities) constructs the digital infrastructures of smart, sustainable and inclusive growth. It also serves to highlight the data management systems capable of supporting the renewable energies of smart buildings. Kourtit et al. (2013) report on the performance of these smart city developments and networking of the digital infrastructures (see also Komninos, 2014). What follows concentrates on the networking of these infrastructures as urban and regional innovations and those which constitute the data management systems of the renewable energy, smart buildings, and transport that sustain an inclusive growth of communities as the neigbourhoods of city-districts.

The Triple Helix-inspired model

The metrics for this Triple Helix-inspired model of a future-internet-based governance is drawn from the Smart Cities inter-Regional Academic Network [SCRANs] performance measurements of nine small, medium and large-scale urban centers (Deakin, 2010; Cruickshank, 2011). Here they are recast to reach beyond the measurement of performance reported by Lombardi et al. (2012) and Kourtit et al. (2013). This is achieved by extending these performance measurements into the informatics of smart cities and analyzing the contribution the digital infrastructures pioneered as the data management system of this future internet-based governance model make to urban and regional innovation. In this respect, the metrics compiled to measure the contribution of these infrastructures are one-sided: that is, centered on the informatics of the digital infrastructures, which underpin the data management systems supporting the energetics of smart cities as urban and regional innovations.

The modulation of these infrastructures is dealt with elsewhere and in terms of the metrics for the sustainable development of communities which transcends the digital spaces that it otherwise creates and into a physiology which includes the data management systems that underpin the growth of renewable energy in smart buildings: that is, in smart buildings whose transportation supports the neighbourhoods of these

urban and regional innovations as city-districts which take on the status of “energy efficient-low carbon zones” (see Deakin et al. 2104 and 2015). [4]

As such, the metrics set out in the rest of this paper can be seen as the “first cut” into a future internet-based governance able to model the informatics, vis-à-vis digital infrastructures and data management systems of smart cities, by way of the Triple Helix-inspired model and through the metrics of the future internet-based governance of that urban and regional innovation which communities can stand by as measurements of performance.

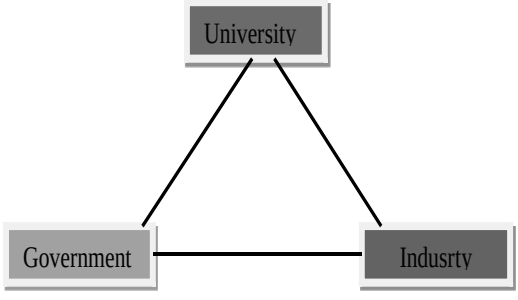

Figure 2: The original Triple Helix
Source: Lombardi et al. (2012)

[4] The reason why this district scale of analysis is of such interest is because it is here that the infrastructures and services not only link with one another, but also connect as the site of those material flows referred to here as either the informatics or energetics of the smart city manifold.

Original Triple Helix

The original Triple Helix (see Etzkowitz 2002, 2008) analyses the three main helices of the innovation system, i.e. University, Industry and Government (see Figure 2). However, in this representation of intellectual capital and wealth creation, little attention is given to the relationship ICT has to the urban and regional innovation, let alone the social capital, cultural attributes and environmental qualities this produces as vital signs of the knowledge economy.

Advanced Triple Helix

According to the representation of the Advanced Triple Helix set out in Figure 3, the knowledge stock is generated from:

- the interplay between universities and industry and what this contributes to the governance of these institutions;
- the collective learning mechanisms which emerge when universities, industry and government bodies act together in searching for efficient public management solutions and that in turn resonate as the knowledge base of innovation processes;
- the "thickness" of the institutions participating in the innovation process, along with the products this creates as a means to serve the social needs, cultural requirements and environmental values of the urban and regional innovation system. This is probably the element most strikingly absent from the original Triple Helix model and goes some way to explaining the lack of trust there is in the ability of the public realm to serve such needs and meet their requirements;
- the interaction between university and industry. As pointed out in Etkowitz (2002), the European Innovation System is relatively laggardly in this respect, while laws fostering such interactions, such as the Bayh-Dole Act in the US, may provide positive incentives for establishing successful research activities;
- the interplay between university, industry and government in what here is labeled 'learning': that

situation in which public institutions learn about how to improve performance and way to take advantage of a better-educated workforce;

- an efficient market, based on well-defined rules and functioning institutions that not only guarantees cooperation between the independent and state sectors, but which also enhances the interrelations among universities, industry and government in those places where knowledge is produced.

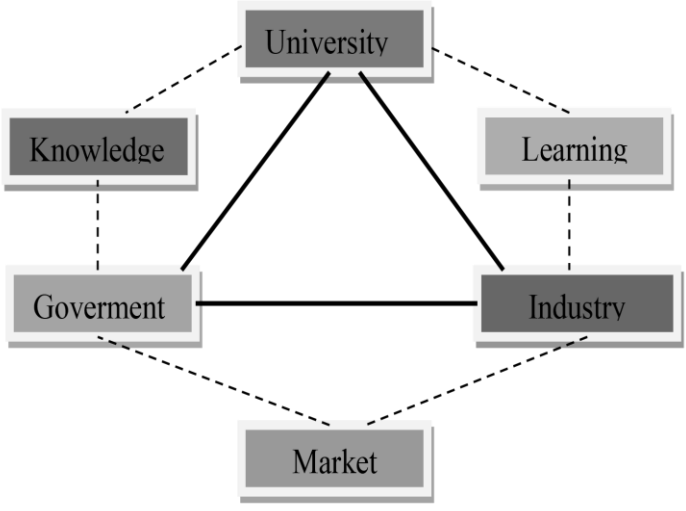

Figure 3: The Advanced Triple Helix
Source: Lombardi et al. (2012)

It is these elements, i.e. knowledge, learning and their institutionalization as the social, cultural and environmental metrics of the market that form the material by which such a network is able to appropriate the innovative capacities of the urban and regional system. Whereas traditional smart city performance measurements focus on the digital infrastructures of future internet-based technologies, Caragliu et al. (2011), Lombardi (2012) and Kourtit et al. (2013), all use the Triple Helix to model the data management system and develop a

broader perspective on growth based on an approximation of this as an urban and regional innovation.

Context	Institution	Measure
Original Triple Helix	University	University [% people aged 20-24 enrolled in tertiary education]
Original Triple Helix	Industry	Industry [Number of companies per 1,000 pop.]
Original Triple Helix	Government	Government [% labour force in government sector-L to Q: Public administration and community services; activities of households; extra-territorial organizations]
Advanced Triple Helix	Learning	Learning (labour force with ISCED 5 and 6 education)
Advanced Triple Helix	Market	Market [Per capita GDP]
Advanced Triple Helix	Knowledge	Knowledge [Patent applications to the EPO per 1,000 inhabitants]

Table 1:Triple Helix data
Source: Kourtit et al. (201

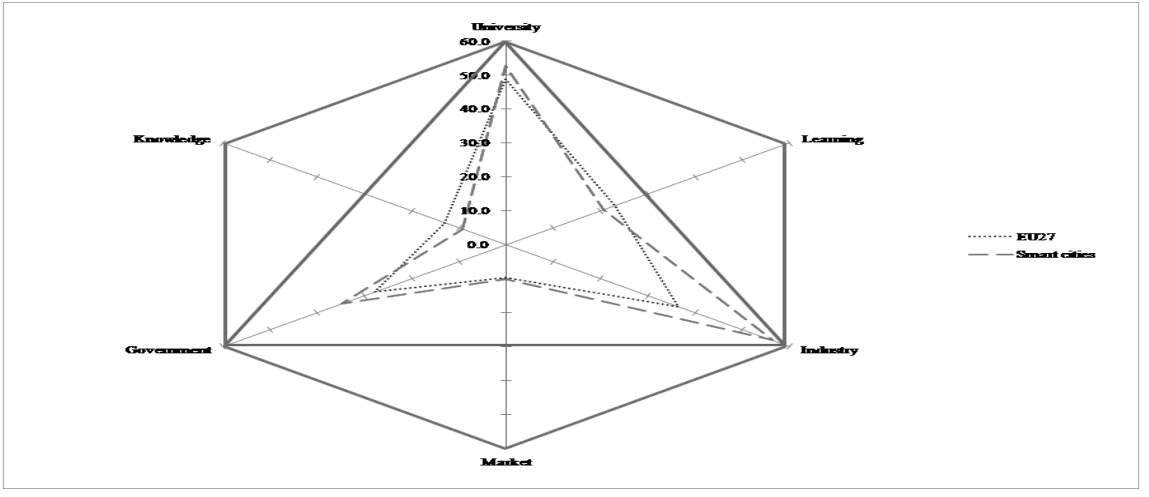

Figure 4: Contours of the Advanced Triple Helix
Source: Kourtit et al. [2013]

The metrics compiled to approximate the contours of the evolving infrastructure system are set out in Table 1. This serves to highlight the initial and additional measures advanced for the Triple Helix of smart cities. As can be seen, this addition modifies the existing model by instituting measures that include learning and which advance into both the market and knowledge domains. While this mirrors the innovation indicators set out by the EC for member-states, the model also allows for such measurements to be drawn at the sub-national, i.e. as part of a comparison between the underlying performances of EU nation-states and infrastructure systems supporting urban and regional innovation. The data sources used for the purposes of this comparative analysis are drawn from EUROSTAT[5] and Urban Audit[6].

The results of this multi-scalar analysis (across the nation-states and sub-national level) of smart city performances, is set out in Figure 4. This shows that the performance of smart cities is above the EU average. As such, they have a greater proportion of young adults engaged in higher education, a larger share of the labour force in industry and government sector. However, while smart cities match the average EU performance in terms of the market, they slightly under-perform in learning and knowledge when compared against the EU average. Lombardi et al. (2012) and Kourtit et al. (2013) both note that while Figure 4 indicates that smart cities tend to out-perform nation states, these dimensions of the Advanced Triple Helix are unable to account for the significance of digital infrastructures as data management systems. In conducting such a measurement, Kourtit et al. (2013) compile an index to measure what the performance of these infrastructure systems is based on:

- percentage of households with internet access at home;
- proportion of households with broadband access;
- proportion of population aged 15-64 with some college education living in Urban Audit cities;

[5] http://ec.europa.eu/eurostat/data/database

[6] http://ec.europa.eu/eurostat/web/cities

- annual expenditure of the Municipal Authority per resident;

Here ‘spatial variance’ is calculated by means of a Principal Component Analysis (PCA). This shows that the first component (percentage of households with internet access at home) explains 40% of the total variance and is termed “Smartness”. This measure has particular significance because it not only indicates the extent to which digital infrastructures are present as broadband technologies, but also approximates the availability of Web2.0 services as data management systems for the development of large-scale participatory governance processes. Large-scale governance processes whose urban and regional innovations in turn regulate how businesses and citizens participate in their application as stakeholder communities.

As a black box, the significance, which this indicator has for the Smart City Ranking model is not known. Nor for that matter, does the collaborative logic of the Future Internet development thesis approximate any such measure. As a multivariate statistical technique, PCA does allow for such an approximation. It does this by identifying patterns in the data set out in Table 1 and then compressing them into a single subcomponent able to maximize the variance. This process has the advantage of reporting the amount of variance in the data explained by each aggregate index. In practice, this allows the original data to be standardized as a covariance matrix able to compute the eigenvectors. This generates eigenvectors, ordered in relation to associated values. In line with the Jollife-amended Kaiser criterion, those eigenvectors with the highest values are selected in relation to the proportion of variance they account for.

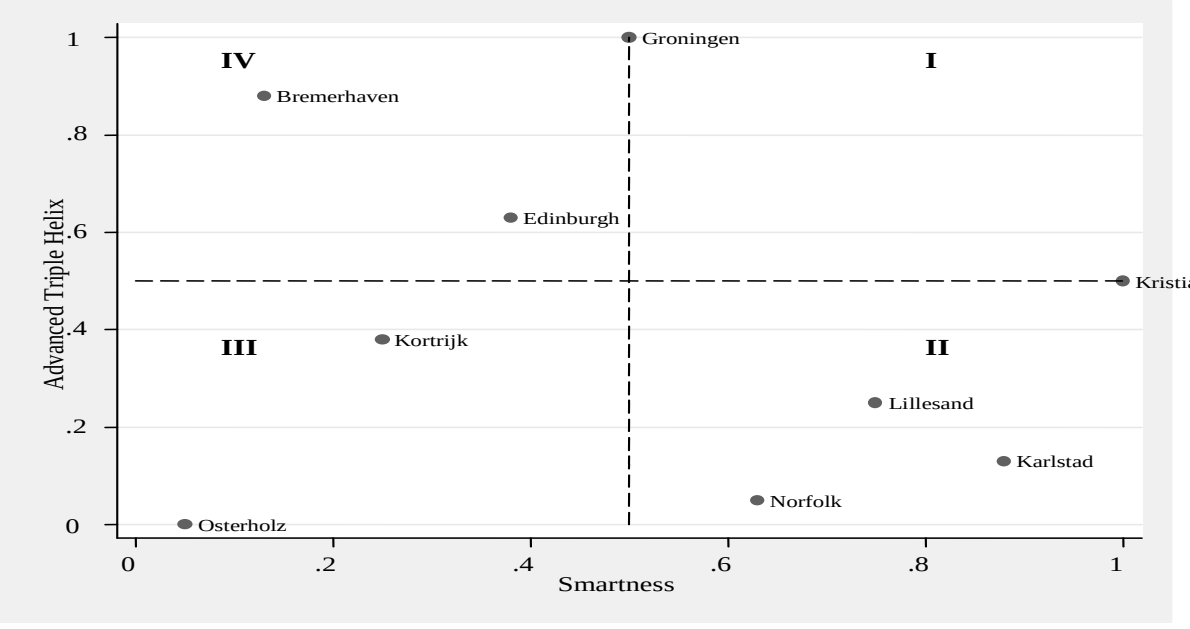

Figure 5: Smartness of the Advanced Triple Helix
Source: Kourtit et al. [2013]

Figure 5 relates the resulting aggregate indicator of smart cities with the future internet-based governance of the Advanced Triple Helix model and suggests smartness relates to the roll out of digital infrastructures. Here the X-axis labelled "smartness" shows the rate of broadband penetration, while the Y-axis is the composite indicator for the Advanced Triple Helix. These two indicators have a Pearson's correlation index of 0.84, significant at all conventional levels. This suggests that a broader definition of Smart Cities as the future internet developments of the Advanced Triple Helix model serves to extend the composition of smart cities from the digital infrastructures underpinning them towards the data management systems they in turn support.

The graph shows a vertical and a horizontal dashed line corresponding to half distribution in terms of both indicators. It identifies four quadrants (first quadrant on the top right of the graph reading clockwise). How the smartness of these cities stands up to the Advanced Triple Helix is notable, in the sense the performances are only equaled by the degree this network of cities is also seen - on this count of smartness at least - to stand apart and fall short of this measure.

As Kourtit et al. (2013: 206) state: the noticeable outcome of this ecosystem is that:

"no city scores high with respect to both indicators, highlighting a potential direction for future improvement. In quadrant II we observe cities scoring high in terms of ICT endowment, but relatively worse in terms of structural innovation-oriented characteristics. In Quadrant IV the opposite happens, with cities showing a good performance of traditional triple helix elements, but less rich in terms of ICTs. Quadrant III, finally, shows two cities with potential for improvement along both dimensions".

This suggests:

- Quadrant 1 does not contain any cities, only Groningen and Kristiensand, which serve to set the contours of smartness in relation to the Advanced Triple Helix.

- Quadrant 2 contains Lilliesand, Karlstad and Norfolk, that all perform well in terms of smartness, but not in relation to the Advanced Triple Helix;
- Quadrant 3 contains Osterholz and Kortrijk, neither of them perform well in terms of smartness or the Advanced Triple Helix;
- Quadrant 4 contains Bremerhaven and Edinburgh, both of them performing well in terms of the Advanced Triple helix, but not in relation to smartness.

Edinburgh provides a good example of this tendency for cities to perform well in terms of the Advanced Triple helix, but not in relation to Smartness. For while it performs well in terms of the Advanced Triple Helix and was the first city In Europe to declare itself 'smart', its digital infrastructures and broadband services have not managed to "go the last mile": that is, generate the demand by which to pull up the rates of participation in the community, either from businesses or citizens as members of the public.

Figure 5 also indicates those cities in Quadrant 4, which perform particularly well in terms of all the six dimensions of the Advanced Triple Helix. By contrast, the performance of those in Quadrant 3 rests on the original Triple Helix. Those in Quadrant 2 do not perform well in terms of either the Original or Advanced versions of the Triple Helix. This is because they concentrate instead on the institutionalization of those digital infrastructures that underpin the broadband of Web2.0 services and data management systems which they in turn develop to support such a future internet-based governance.

This serves to reiterate the key message drawn from the modified Triple Helix model: the current absence of suitable policies on the informatics, vis-à-vis digital infrastructures of data management systems of smart cities, means the intellectual capital of these technologies do not create the wealth that is needed for communities participating in future internet-based developments to meet the challenge which the governance of them pose businesses and citizens alike.

As Leydesdorff and Deakin (2011: 57) point out, this "standing apart and falling short" is something into which the future

internet-based governance of smart cities offers a critical insight: in particular, into the tendency there is for the reflexive instability of the intelligence embedded in the social capital, cultural attributes, and environmental qualities of the Advanced Triple Helix model, to produce a "creative slack"[7]; more specifically, to produce a creative slack (as indicated in Quadrants 3 and 4 of Figure 5) sufficiently strategic for any meta-stabilization of the growth in the infrastructure systems of this urban and regional innovation to be fundamental; that is to say, for Quadrants 3 and 4 to provide a basis upon which to cultivate an environmentally sustainable reconstruction of those infrastructure systems whose technologies are able to draw upon any creative slack in the knowledge economy.

This in turn suggests that in order for the governance of this future internet development to "pick up the slack", be fundamental and constitute the grounds on which to configure the infrastructure systems of an urban and regional innovation smart enough for cities to sustain such growth, it is necessary to extend the digital infrastructures that underpin them into the data management systems which support the energetics of those renewables servicing the building and transport sectors as an application of such technologies. For only in this way i.e. as technological applications in the energetic of renewables installed in buildings and transportation networks, can the cities in Quadrant 2 move up into 1 and those in Quadrant 4 be smart enough to sustain this as a process of inclusive growth.

Conclusions

This paper captures the state-of-the-art on smart cities and identifies three emerging accounts of their performances. Listing them chronologically, the emerging accounts are of Smart City Rankings, Future Internet developments and the Triple Helix model of smart cities. In capturing this state-of-the-art, it finds the Smart City Ranking model to be a black box and the Future Internet only accounting for the development of

[7] An explanation for this slack, rooted in the research and technical developments of smart cities and as urban and regional innovation systems founded in the intellectual capital of wealth creation, can be found in Deakin (2014) and Deakin (2015).

digital infrastructures, it suggests the metrics for ranking this future-internet based governance by way of the Advanced Triple Helix model of smart cities and through the data management system of the urban and regional innovation it founds, serves to overcome the limited reasoning of the former and reach beyond the somewhat open-ended collaborative logic of the latter. It achieves this by allowing the intellectual capital of the technologies smart cities are pioneering as the digital infrastructures of a future internet-based governance to support that process of wealth creation which underpins the data management system of this urban and regional innovation.

This critical synthesis of the Smart City Ranking and Future Internet accounts allows the future internet-based governance thesis to overcome the criticisms of the Triple Helix model's representation of urban and regional innovation made by the likes of Cooke (2005) and Carayannis and Campbell (2012). The extent to which the technologies of the future internet-based governances stand up to the smartness of the Advanced Triple Helix model is also notable, in the sense that such a test of cities serves to reiterate the key message drawn from the assessment of smart cities made by Leydesdorff and Deakin (2012). Namely, the current absence of suitable policies on the digital infrastructures of data management systems means that smart cities do not possess either the academic leadership needed, or corporate strategies required for the informatics of future internet developments to meet the energetic standards laid down for those claiming to sustain such developments (also see; Deakin and Leydesdorff, 2013; Deakin, 2014, 2015).

This "standing apart and falling short", is something that offers a particularly critical insight into the future internet–based governance of such developments: in particular, the tendency there is for the reflexive instability of the intellectual capital embedded in the social capital, cultural attributes and environmental qualities underlying the technologies of this urban and regional innovation, to surface as a "creative slack". More specifically, to surface as a slack in the creation of that wealth which is needed for the economies of the digital infrastructures that underlie the management of this data to support the energetic of urban and regional innovation. To be

exact, sustain the energetic of that urban and regional innovation in which the management of data creates the wealth that is necessary for digital infrastructures to pick up this slack and generate the intellectual capital of those technologies smart enough for the renewable energies, buildings and transport of cities to sustain an inclusive growth of neighbourhoods as the energy efficient-low carbon zones of city-districts.

This serves to highlight why the attempts made by the likes of Manchester, Malmö, Amsterdam and Barcelona to build on digital infrastructures by overlaying them with data management systems is so significant. For without them any future internet-based governance should not have the intellectual capital which is needed for the technologies of renewable energies, building and transport sectors to augment that process of wealth creation any Advanced Triple Helix model ought to account for.

Lombardi (2012) and Kourtit (2013) list the additional indicators needed for the PCA to achieve this. Along with Deakin et al. (2014; 2015), they provide the measures by which to extend analysis of this urban and regional innovation beyond the informatics of digital infrastructures that act as data management systems and into the energetics of the renewable energies, building and transport sectors and which are required to sustain these technologies as applications of particular concern to the stakeholder communities affected by them.

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