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A model for the analysis of data-driven innovation and value generation in smart cities' ecosystems

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ABSTRACT

Smart cities are key elements to cope with certain of the largest challenges facing society, such as overpopulation, transport, pollution, sustainability, security, health, and the creation of new firms. Smart cities' portals offer a great amount of data that can be used by the private and public entities to create new services. These data are also a valuable source for the deployment of big data businesses. In this article, a model is presented demonstrating how the data released by the smart cities creates value for the citizens and society. The model operates using three stages. The first one shapes the release of data by the smart city, and it includes several of the dimensions that make data appealing for reuse. The second stage analyses the mechanisms to create innovative products and services. The last stage explains how these products and services impact its society.

1. Introduction

Worldwide data production is steadily growing as a consequence of the popularity of mobile connections and the emergence of the internet of things. As an example, mobile data grew 74% in 2015 according to Cisco's calculations (Cisco, 2015), and eight-fold growth from 2015 to 2020 is expected, reaching more than 360 exabytes. In this scenario, smart cities' ecosystems become remarkable active participants.

The importance of economic impact derived from the use of government data has been analysed from a theoretical perspective (Carrara, San Chan, Fischer, & Van Steenbergen, 2015; Dekkers, Polman, Te Velde, & De Vries, 2006; Vickery, 2011). Data must be released so that people and organisations can have the opportunity to create new information and services (Marcos-Martín & Soriano-Maldonado, 2011; Mulley & Moutou, 2015; Weiskopf & Weng, 2013). Smart cities participate in increasing data production to a point where the relation between big data and smart cities could be considered an emerging trend for scientific research and professional services (Al Nuaimi, Al Neyadi, Mohamed, & Al-Jaroodi, 2015; Kitchin, 2014; Townsend, 2013).

By generating and compiling large quantities of data, smart cities can improve their internal processes and put into action collaborative options to create value for its citizens. The current trend is to publish the data in new reusable streams and datasets, encouraging its ecosystem (i.e., citizens, private companies and social organisations) to create new and innovative services (Abella, Ortiz-de-Urbina-Criado, & De-Pablos-Heredero, 2015a). However, producing an increasing amount of data does not imply the creation of any value or appreciated services for citizens. Creation of value out of this plethora of data sources calls for a framework that drives investments in data production, publishing and promotions. According to Jetzek, Avital, and Bjorn-Andersen (2014a, 2014b), innovation is one of the main value creation mechanisms.

Carrara et al. (2015), Dekkers et al. (2006), Pira International (PIRA) (2000), and Vickery (2011) assess the potential of value creation derived from Public Sector Information (PSI) using surveys and estimations. However, there is a lack of studies that can demonstrate this value creation, and they strong differ in terms of economic outcomes (Red.es, 2012, 2015). None of these studies provide a framework to understand how the value is created.

Therefore, it is important to understand how data-driven innovation is critical, particularly in terms of its creation of social and economic value for the society. Otherwise, cities' decision makers will risk wasting their scarce resources on initiatives that would be irrelevant for its citizens. This article presents a new model describing the mechanisms for value generation as a consequence of data release in smart cities. The model operates using three stages. The first one shapes the release of data by the smart city. It includes some dimensions that make data appealing for reuse. The second stage analyses the mechanisms to create innovative products and services. The last stage explains how these products and services impact its society.

2. Data-driven innovation in the smart cities

Smart city has been extensively defined (Giffinger et al., 2007; Hall, 2000; Nam & Pardo, 2011a; Washburn et al., 2010), but it still remains

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an ambiguous concept (Vanolo, 2014). Some of the aspects that are the most frequently emphasised are: sustainable (i.e., energy consumption), sensor (i.e., sensors providing data), and collaborative (i.e., citizens' participation) (Abella et al., 2015a).

Angelidou (2015) affirms: "*Smart cities represent a multidisciplinary field, constantly shaped by advancements in technology and urban development*". Smart cities have also been defined as social entities focused on human interaction. Previous authors have considered how this interaction creates conditions for the development of innovation, business creation, and positive health conditions (Hara, Nagao, Hannoe, & Nakamura, 2016; Kylili & Fokaides, 2015; Walravens, 2015). Smart cities are also urban entities, and their layout, governance, infrastructures, and availability of facilities could relieve or aggravate the existing issues (Nam & Pardo, 2011b; Wiig & Wyly, 2016). Hollands (2008) debates the definition of smart cities in a modern urban context. This researcher considers two aspects: the technological and the human (human capital, social learning and creation of communities). Vanolo (2014) states that the smart city discourse is the "*history of urban imaginaries*", and presents two dimensions: green/sustainable city and technological/informational city.

This article considers the new possibilities of digital interaction between citizens and city services on transport, security, businesses generation, and standards of living, etc. Accordingly, a smart city is defined as, "A public-private ecosystem providing services to citizens and their organisations with strong support from technology, and considers the social and economic impact on the society".

The released data of a smart city nurtures a lively ecosystem composed of agents (i.e., groups of companies and non-profit organisations) that create innovative products and services (Da Cruz & Marques, 2014; Schleicher, Wien, Vogler, Dustdar, & Inzinger, 2016). Data-driven innovation has been formerly studied by Kusiak and Tang (2006) and Kusiak (2009) as a tool for the generation of innovative products and services. Data-driven innovation from public data sources can be considered a business innovation when the exploitation of data is made by private entities. This innovation can generate a positive economic and social impact (Jetzek et al., 2014b).

The agents of the ecosystem also incorporate other shared digital data. Agents deliver new and innovative services to society by using released data and innovative processes to create added value. These services must often compete with those created directly by the smart city; and accordingly, they must exhibit additional value based on innovation. Society demands incentives for the creation of new services, which in turn, requires additional data from the city. To succeed, the city must implement participatory channels, and not only deal with the new data requirements but also provide feedback on inadequate information detected by any agent. In that sense, this model is aligned with the open government principles, namely: transparency, which publishes internal data from the public administration; participation, which are the services created due to society's demands; and collaboration, which is the closing link between data sources and agents that is required to achieve sustainability (Lee & Kwak, 2012). Fig. 1 represents the digital ecosystem around a smart city.

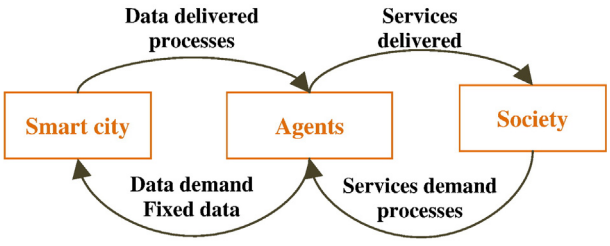

Fig. 1. Digital ecosystem around a smart city.
Source: adapted from Abella, Ortiz-de-Urbina-Criado, and De-Pablos-Heredero (2015b).

Smart cities offer a variety of public data through portals (Belanche, Casaló, & Orús, 2016). Marcos-Martín and Soriano-Maldonado (2011) recognise how this information reuse has made possible the creation of new companies with limited equity holding business models that develop added value to products and services based on enriching the released data. In that sense, the literature on data reuse pays attention to the use of data and the analysis of the economic value derived from the efficient use of public resources (i.e., efficiency), and/or creating new products and services (i.e., innovation) (Caceres & Royds, 2015).

Some studies analyse specifically the use of data from public administrations and cities. For example, Tsai (2009) and Un, Cuervo-Cazurra, and Asakawa (2010) explain how the use of data generated by firms, universities, and research institutes impacts positively the innovation capability of firms and public administrations. It is also true that some authors recognise the lack of ability that some firms and public administrations have to absorb these data (Fey & Birkinshaw, 2005; Huang & Rice, 2009; Inauen & Schenker-Wicki, 2011). Recently, Ojo, Curry, and Zeleti (2015) analysed the role of open data in the context of smart cities' initiatives by examining 18 cases across 5 smart cities. Their findings revealed the potential impact of open data initiatives on smart cities' domains, and disclosed an inherent "open innovation economy" impact pattern.

Bakici, Almirall, and Wareham (2013) have also analysed innovation in smart cities. A direct co-creation in living labs with citizens using open data that impacts the creation of smart ideas and services has been found. Additionally, Hielkema and Hongisto (2013) analysed the development of services based on open data released in the smart city of Helsinki and how healthy competition has encouraged the growth of innovative services.

Data-driven innovation has also been found to impact a society. In that sense, Jetzek et al. (2014a) describe a full model of value creation based on open government data and how several factors, such as open access, resource governance, capabilities and technical connectivity, contribute to four constructs, including efficiency, innovation, transparency and participation. Their findings demonstrate that innovation stands out as the most influential factor for social and economic impact. Their concept of economic and social value reviews the initial concept developed by Moore (1995), and further extended by Benington (2011) under the concept of public value, that is, "*first, what the public values and second, what adds value to the public (sphere)*". Jetzek et al. (2014a) choose social and economic indicators based on Stiglitz, Sen, and Fitoussi (2009) that are comprised of several dimensions: material living standards; health; education; personal activities, including work; social connections and relationships; environment; and insecurity.

Diener and Suh (1997) analyse and discuss the measurement of economic and social value from the standpoint of quality of life. They review the different existing definitions and remark that they lead to different social and quality of life indicators; however, some of them are hardly available. Although there is a clear correlation between social indicators of quality of life and life satisfaction, the connection is indirect. Several countries with similar social indicators present abrupt differences in life-satisfaction metrics. In their study, they highlight that the psychological dimension that a human being introduces adds complexity because of people's subjective perception about social value and economic value.

Porter and Kramer (2011) approach the social and economic value from the firm's standpoint, and coin the term *shared value* to combine both values. For these authors, shared value specifies the creation of economic value in a way that also creates value for society. Shared value differs from social responsibility, philanthropy, or even sustainability because it is the current goal of a company to guarantee survival in the long term. The concept, inherently economic, is focused on firms, but it is rooted on society's needs, including social value.