How “smart” are Latin American cities?

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Abstract

This paper argues for the use of composite indicators to assess the “smartness” of the management of cities and illustrates it in a comparison of 6 large Latin American cities. The analysis is based on 6 dimensions commonly used to define city smartness in the recent academic literature in terms of technology, physical and human capital as well as policy. It quantifies each of these dimensions with relatively easily available public data to ensure the transparency of the evaluation and of its updating. The quantification required a normalization of the data and the computation of weighting factors for each indicator to delete redundant information since various dimensions used to characterize smartness in the literature are correlated. The results allow an evaluation of individual areas in which each city can improve as compared to best practice. The synthesis of these multiple dimensions into a composite single score index is then used to rank the cities on their overall performance as well. All performances are benchmarked against Amsterdam’s performance, considered to be best practice in many dimensions. The Latin American cities covered by the sample, including Santiago, the best regional performer, are found to significantly lag best practice, although on some dimensions, some of the cities do better than the benchmark.

[1] We are grateful to A. Okubo, M. Parenti and T. Serebrisky for useful discussions. Any mistake or misinterpretation should only be blamed on us.

1. Introduction

Dealing with the local consequences of rapid demographic growth, cities are facing changes driving them to find innovative management and organisational approaches. Uneven economic growth, underemployment, crime and violence, growing poverty, climate change, increasingly binding fiscal constraints, corruption or growing political and governance complexity are some of the most obvious challenges city managers have to address. This implies the search for smart uses of modern technologies to help address these challenges as it has been fashionable to argue for a while now. But just as importantly, it implies the smart use of all the human and physical resources available to improve the well-being of citizens since technologies do not (yet) offer an answer to many of the challenges. The extent to which cities manage to address them in the interest of the majority of the population and businesses is, ultimately, what should define how "smart" they are.

Getting a comprehensive sense of the extent to which cities manage to take on the challenges they face is not as simple as it may sound. Some cities may perform well on some dimensions while doing poorly on others. To measure performance with respect to each dimension while highlighting possible trade-offs, one approach is to identify specific quantitative indicators for all relevant policy areas. These indicators can be used to benchmark the city performances for any given issue. And they can also be used to produce a synthetic indicator providing a global snapshot of the city's overall smartness. Clearly, the robustness of the approach is quite sensitive to the specific choice of indicators and this is linked to be the availability of data. But it is usually robust enough to allow key stakeholders to shift the burden of proof onto the city managers. If managers argue that they are doing better than suggested by these simple indicators, they need to come up with evidence. The resulting increased accountability is an often underestimated payoff of an approach which allows both an absolute and relative ranking of cities. Its simplicity, despite its limitations, may explain why it is quite popular in policy circles as illustrated for instance by those produced for high profile rankings such as the World Competitiveness or the Doing Business reports used to rank countries on multiple dimensions and widely quoted in the media.

Showing that such an encompassing synthetic indicator of city "smartness" could help fuel a policy oriented monitoring of the extent to which cities are managed in a sustainable way making the most of their physical, human and technological endowments is the main purpose of the paper, with an illustration for six Latin American countries (Bogota, Buenos Aires, Lima, Mexico City, Rio de Janeiro and Santiago). The concern for "smartness" in city management is particularly obvious in Latin America because it is one of the most urbanized in the world. By 2050, its urbanization rates are expected to reach 90% (Arsht, 2014). And this fast urbanization is happening in a complex social and political context. But to assess the relative importance of the size of the challenge for the region, it is useful to also have a best practice benchmark against which to compare the performance of each city of the region on each dimension and overall. This is why we also computed the index for Amsterdam, which will serve as a *reference city*, as it is widely considered as one of the smartest cities worldwide (e.g. Okubo, 2017).

The paper adds to the recent academic and consulting literature efforts to come up with city rankings internalizing the multiple dimensions of smartness. The oldest and best publically documented efforts have been conducted for European cities, internalizing the early insights on what drives smartness. These include notably Giffinger et al. (2007) and Lazaroiu and Roscia (2012). There are also more "commercially" oriented, but less analytically transparent, city ranking produced by consulting firms. They usually have somewhat narrower focuses than the one adopted here and almost all include more subjective measures that the more academic rankings do. For instance, Mercer assesses the quality of life in cities to size up hardships differences in 200 cities (only 5 Latin American) for firms with internationally mobile staff. Kearney focuses on the scope for cities to foster growth, jobs and quality of life, covering 15 Latin American countries (mostly the capital cities of the region). The Economist has its own ranking based on 30 factors (many subjective qualitative assessments) spread over stability, infrastructure, education, health and environment. It covers a good range of Latin American cities. The closest ranking to the one adopted here is conducted by the IESE business school of the University of Navarra (Spain). It classifies 181 cities (29 in Latin America (1 in Chile, Guatemala, Peru, Dominican Republic, Uruguay and Venezuela, 2 in Bolivia and Ecuador, 3 in Argentina, Columbia and Mexico, 9 in Brazil)) along 10 dimensions approximated by 77 indicators. Unfortunately, there is little detail on the analytical treatment of the raw data to be able to produce a detailed comparison with any of the rankings covering Latin America even if their choice of dimensions overlap reasonably well with those adopted here[2]. Moreover, the rankings are less focused on the policy implications of the analysis than we are in this paper.

To illustrate the policy relevance of the measures, we use the individual and overall index computed to discuss the relative importance of challenges that the cities are facing and the margin they have for improvement. In addition, we look at the correlation between various dimensions and the technological performance of each city to highlight the extent to which the scope for technological progress has been built in some of the other management dimensions. The assessment can only be preliminary because of significant data gaps and quality issues. In particular, we had to rely on country indicators rather than city indicators for some dimensions. This implies that, for some dimensions, we may be closer to measure the smartness of countries rather the smartness of cities. However, for the countries covered, the dimensions analysed (economic strength, environmental quality, governance, human capital, infrastructure and living standards) of the country are often well reflected in the management of the city analysed. Hence, the analysis is expected to be relevant as a first cut, even if a more thorough assessment could be more directly policy relevant.

To get to this policy discussion, the paper is organized as follows: Second 2 reviews the literature on smart cities, highlighting the evolution of the concept and the growing consensus on the multiplicity of dimensions to account for. Section 3 describes the methodology used to quantify the degree of smartness on 6 dimensions and then to produce a single composite

[2] For Mercer, https://mobilityexchange.mercer.com/Insights/quality-of-living-rankings, for Kearney, https://www.atkearney.com/documents/10192/12610750/Global+Cities+2017+-+Leaders+in+a+World+of+Disruptive+Innovation.pdf/c00b71dd-18ab-4d6b-8ae6-526e380d6cc4), for the Economist, http://www.smh.com.au/cqstatic/gxx1l4/LiveabilityReport2017.pdf). It covers a good range of Latin American cities for IESE, http://www.iese.edu/research/pdfs/ST-0396-E.pdf.

indicator aggregating all the information. Section 4 describes the data (and more details are provided in Appendix 1). Section 5 discusses the results. Section 6 emphasizes the evidence on the correlation between the technological characteristics of the city and the other dimensions of interest in the common diagnostics of cities performance. Section 7 concludes.

2. Literature review on the evolution of city smartness coverage

The concept of "smart cities" can be quite frustrating to deal with because it is subject to recurring disagreements, notably on the number of dimensions that should be accounted for to assess the degree of smartness of cities[3]. The term "smart" itself has stirred up controversy from the beginning when applied to a city and its use has been in constant evolution over the last 10-15 years as mentioned by various authors (Angelido, 2014; Caragliu et al., 2011; Hollands, 2008; Kumar et al., 2017; 'Grady and O'Hare, 2012).

Initially, city smartness was part of the concept of 'digital city' (Anthopoulos and Tsoukalas, 2006; Albino et al., 2015; Alawadhi et al., 2012). Thereafter, many authors (Graham and Marvin, 2001; Graham, 2002; Komninos, 2002) argued that Information and Communication Technologies (ICT) lied at the core of the smart city idea because they foster all networked infrastructures (transport, business services, housing, public and private services). Although some observers of the debate continue to mainly focus on the role of ICT, in practice, most practioners and academics have now moved well beyond this technological focus to also include dimensions that characterize the sustainability, effectiveness and accountability of city management. The definition still covers the contribution and the management of new technologies in cities, their effect on the city's performance and the governance in the economy and durability (Attour and Rallet, 2014), but it includes many more dimensions less directly related to ICT as well.

The evolution in the scope of dimensions covered is consistent with the growing concerns for the ability of cities to manage change when multiple dimensions are evolving simultaneously. The dynamics and the political sustainability of the improvements needed to make a city well managed are much more complex than its ability to internalize technological progress. To become really smart, cities need to adopt and commit to continuous processes to make the most of the opportunities to rely on ICT to achieve efficiency gains, attractiveness, social inclusion and environmental goals (Pfaeffli et al., 2016). They also need to internalize the complexity of social interactions in urban spaces (Albino et al. 2015) and this means that the reduction of social exclusion should be on the agenda for a city to be considered smart (Taipale et al., 2012; Martin, Hope, and Zubairi, 2016). Social inclusion implies access to an elementary level of services for all citizens (public transport, water, sanitation, electricity, telecommunications, education). This involves avoiding smart services to be confined to wealthier areas (IEC, 2014) as well as ensuring access to health and protection from crime risks for all citizens.

Some authors add that the aim should not just be the elimination of poverty any more, but also include specifically the decrease of inequality (Taipale, LeBlanc, and Fellini, 2012). And in all

[3] Besides the disagreements on substance, there is also a disagreement as to when the concept of smart city was born. Some authors argue that the seeds of today's smart cities were developed in 1980s (Cocchia, 2014; Glasmeier and Christopherson, 2015) while others claim that the term smart city has emerged since the late 1990s (Albino et al., 2015; Anthopoulos, 2015; Raj and Dwivedi, 2017; Kumar et al, 2017).

cases, as argued by Barry and Glaeser (2005), Glaeser (2005) or Neirotti et al. (2014), city managers need to internalize the role of human capital in making the most of opportunities to improve because it drives the effective use of ICT to make cities smart. For instance, there is still a need to take into account that some of the population has low or non-existent literacy levels, which is a significant hurdle to technology integration. Indeed, the potential of technologies will not be exploitable if citizens are not trained to use them or do not have access to the internet for instance (Maciag, 2017). In many cities, there is a real "digital divide" (Datta, 2016), which is both the consequence of mismanagement and a cause of inability to improve management outcomes.

More recently, analysts have also been emphasizing the effectiveness of governance because of the need to recognize that managing the challenges involves a multiplicity of actors and stakeholders (Torfing et al., 2012; Leydesdorff and Deaking,2011). A city can only be smart if it is characterized by the collaboration and partnership among various actors, with different implications at the federal, state and local levels. The private sector and non-governmental organizations are involved in a wide range of ways, including as service suppliers, financiers, industry associates, or standards setters. The emerging message from the literature is that addressing societal challenges is not only a matter of implementing good policies but also one of organizing close partnerships between government and other stakeholders (Torfing et al., 2012; Leydesdorff and Deaking 2011; Dameri, 2017; Anthopoulos, Janssen, and Weerakkody, 2016). They all point out the necessity of recognizing the importance of interactions between actors if cities have to make the most of the opportunities provided by technology and research. They all emphasize in particular the relationship of 'University-Industry-Government'. More recently, Lombardi et al. (2012) have suggested adding explicitly the role of civil society as a fourth key actor. In other words, how smart a city is depends on how effectively its governance favours interactions between these actors. Optimized consultation, participation and coordination are important success drivers and are part of the efforts to make to minimize corruption, capture and distortions in the decision-making processes.

In addition to the dimensions discussed so far, the literature points out two more characteristics to be picked up in a diagnostic of city smartness. The first is the state of its infrastructure. To successfully have soft transition to fast urbanization, cities need effective transport system, trustworthy low-carbon energy models and safer water networks (both in terms of supply and quality). Closing the infrastructure gaps and modernizing the sector both play a key role in enhancing the quality of life, equity and social inclusions in cities (Jaitman, 2015). ICT clearly has a role to play in this dimension as well as users are seeking more and more real-time information to help them decide and optimize their personal choices with respect to the use of infrastructure. This is particularly relevant for the efforts to increase the smartness of urban transport and energy sectors (Aoun, 2015; Kieps, 2017; Webb et al., 2011; Zanella et al., 2014).

Finally, as often in policy, the literature also reminds us that financing constraints influence the speed at which city smartness can be achieved. How well cities are managing their financing needs is part of what defines economic smartness to make the most of the opportunities of achieving smartness on any of the other dimensions. For instance, Black and Veatch (2017) argue that the budget constraints are the first hurdle blocking municipalities to develop smart city programs. Along with the digitalization of infrastructure and the emergence of smart cities, there is a global tendency of enhancing the involvement of the private sector in the financing, direct operation of urban infrastructures and public services (Iossa and Martimort, 2015; Rouhani et al., 2016). The approach continues to be popular despite the recurring crisis associated with Public-Private Partnerships (PPPs). A recent British government audit found little evidence that government investment in more than 700 existing public-private projects has delivered financial benefits (National Audit Office, 2018). It shows that the cost of privately financing public projects could be as much as 40% higher than relying solely upon government money that auditors found. These recent events imply a word of caution when considering that the extent to which a city has been able to attract PPPs is a sign of smartness or a reflection of the need to come up with short term financial solutions to lasting fiscal constraints, which may end up having bad long term fiscal effects.

Overall, this literature review should have made it clear that despite the disagreements in a field covered by a vast very multi-disciplinary literature, the academic and policy debates have led to enough convergence to recognize that smartness is multi-dimensional rather than mostly focused on the impact of ICT. More importantly, from a policy perspective, the debate should be about the overall efficiency with which local governments manage to cater to a number of basic needs and concerns. And there seems to be some global convergence on the key dimensions that are likely to characterize this efficient management defining the smart city of the future. These are the dimensions that need to be picked up by any effort to assess the performance of cities in terms of their smartness. Caragliu et al. (2011) made this point early on and identified six key dimensions of a smart city to synthetize the various perspectives: smart Economy, smart Mobility, smart Environment, smart People, smart Living and smart Governance. In practice, to turn this synthesis into a policy tool, the challenge is to come up with specific quantifiable indicators for each of them. Building on this suggestion and somewhat refining it to better account from some of the recurring insights for the more recent literature, we reframe the list as follows. How smart a city is can be assessed based on the smartness of its:

- economy,
- environment,
- governance
- infrastructure
- human capital
- living standards.

Although there is some margin for diversification in approaches, there are a few recurring patterns in the way the literature turns these 6 characteristics into measurable indicators. And on this front, the literature is also quite useful to identify indicators used to proxy each dimension (although most of this is inspired by data available on OECD countries). Some dimensions are divided into several factors (sub-dimensions) in order to have a better overview of city smartness, which in turn are described by indicators.

The degree of economic smartness of a city has been characterized by its degree of competitiveness (which is credited to be related to a city’s industrial structure, its productivity or its geography), by its capacity to innovate or by the relative importance of its informal economy. The environmental dimension tends to be on measures of pollution, congestion, water and waste management. Governance is usually measured through the degree of corruption and when possible by the degree of political (in)stability, the lack of citizen participation, and the cost of doing business as a proxy for bureaucratic excesses. Infrastructure can be approximated by access rates, affordability measures, mobility speed and ICT coverage and quality. The degree of smartness of its human capital is linked to the education levels and standards of its population but also by the degree of digitalisation of the education and by the degree of accessibility of education illustrated by the share of the poor getting access to higher education for instance. Concerning living standards smartness, the most common indicators include its attractiveness in terms of quality, safety, housing or health standards as well as of job opportunity, poverty management, culture and tourists attractions. These can be measured by very concrete dimensions such a share of population living in slums, share of population living under the poverty line, unemployment rate and crime rate to have an idea of the social exclusion challenge as well as of the numbers of foreign visitors, international events or museums.

In sum, the main insight from the literature is that there are many indicators available to quantify the various dimensions of smartness and that which specific measure is used largely depends on data availability and on the importance of correlation between various proxies. The main drawback for the multiplicity of indicators available is that it leaves some degree of discretion to the analysts to decide which one to include/exclude, making comparisons across approaches quite challenging. It is also likely to lead to conflicts because changes in indicators may induce changes in performance perceptions and hence rankings. These risks should be clearer in the following discussion regarding the limitations of the methodology used to come up with a ranking of cities in terms of their smartness.

3. Methodology

The main idea is to be able to rely on a method which: (i) allows the internalization of the latest insights from the debates on what makes a city smart into a single indicator and (ii) which still reflects the relative importance of the key drivers of smartness individually. The paper follows the lead provided by Giffinger et al. (2007, 2010) insights and the methodological improvements suggested by Lazaroiu and Roscia (2012). These two rankings consider cities' smartness in terms of the six characteristics described in Giffinger et al. (2007). Both normalize data on basic indicators reflecting the insights from theory by a transformation that converts these indicators into standardized values with an average of 0 and a standard deviation of 1. The main difference between the two approaches is with respect to the decision to assign a weight to the various indicators or not. Giffinger et al. (2007) aggregate all indicators to a single score by giving equal weighting to the indicators while Lazaroiu and Roscia (2012) compute a weighting factor for each indicator based on experts' opinion, which introduces its own biases.

In this paper, we follow the broad approach adopted by these two papers, but we update the dimensions to account for based on the latest insights in policy and academic discussions of what should be driving "smartness". We also follow the suggestion to weight the indicators since ignoring the relevance of weights boils down to ignoring the relevance of a possible correlation across indicators. Our approach to identify weights is however somewhat different to the approach adopted by Lazaroiu et al. (2012).

More specifically, the approach followed here organizes the analysis in 6 steps.

(1) We identified specific indicators to measure the 6 smartness dimensions and the various factors within each dimension as discussed at the end of section 3, following Giffinger el al. (2007). It also based on the availability of comparable data for any given indicator for all the cities of the region. We discuss more specifically the choices of data in Section 4.

(2) We selected cities, largely based on data availability for each indicator of interest and on regional representativeness in terms of efforts to adopt smart approaches to city management. We added Amsterdam to the list to have a best practice benchmark as part of the analysis. All indicators used to jointly describe the factors of a smart city are open access on the Internet. In total, 39 indicators were selected for the evaluation, whereas 33 (85%) are at local level, 4 (10%) on national level and 2 (5%) are an urban average of the country. The inclusion of national and urban average data is necessary to broaden the database but also because of data quality concerns: more reliable data are available on that level. The most recent data available are used but sometimes, the dataset is completed with older inputs. The dataset consists in data from 2007 to 2017. Appendix 1 reports the specific indicators for each factor for each dimension and the data sources used in the paper.

(3) We normalized the data with the Max-Min method in order to eliminate the bias of scale and to read them all in the same direction.

(4) We computed the weighting factors for each indicator. These were established from a statistical treatment aiming to identify redundant information between indicators.

(5) For each dimension, we summed the weighted indicators in order to get a single score at dimension level.

(6) We developed a composite indicator measuring the city's smartness by aggregated the 6 single scores based on the same method (by normalising, computing weighting factors and summing). This allows us to benchmark the relative smartness of each city compared to the other cities considered in this study; the highest rate the smartest.

Since the steps 3 to 6 are more technical, they deserve the following much more detailed description. It may be easier to start with step 6. To produce a measure of city smartness that accounts for the multiple dimensions, which may themselves be accounting for multiple individual variables, we need to be able to come up with a single smartness score accounting for all of these characteristics jointly. Therefore, the final score is the aggregation of the partial scores achieved on each dimension. Each individual dimension may actually be the aggregation of various sub-dimensions. For instance, how smart the city economy is depends how smart it is in terms of innovation and productivity. Each dimension or sub-dimension is itself a composite indicator obtained from the aggregation of the individual indicators available to characterize the various components. For instance, innovation smartness is approximated both by patent applications and the ranking of the city as an innovative city in an international benchmarking of 500 cities.

Formally, the composite indicator is expressed as

$$I = \sum_{i=1}^{n} w_i x_i, \qquad (1)$$

where I is the composite indicator, x_i is the normalized variable, w_i is the weight of the x_i, $\sum_{i=1}^{n} w_i = 1$, $0 \leq w_i \leq 1$ and i = 1,…,n.

The most challenging part is to come up with the partial composite indicator at a given dimension or sub-dimension level. It requires three steps: (1) a Multivariate Analysis to check correlations between indicators and thus, redundancy; (2) the normalisation of the indicators to provide comparable data; (3) a Principal Component Analysis followed by a Factor Analysis to compute the weighting factor for each indicator considering their redundancy [4]. Once normalized and weighted, the indicators can be aggregated. The final single score for city smartness replicates the approach from the partial composite indicators computed for each dimension. More specifically, these composite indicators for each dimension are weighted (Multivariate Analysis followed by Principal Component Analysis/Factor Analysis) and summed to develop the final single score.

To illustrate the approach, Table 2 provides the data on individual basic indicators for economic smartness of cities. It reports 8 basic indicators, two of which reflect the innovation smartness and 3 the productivity smartness. The data reported is raw and the variables have indeed different measurement units and therefore, cannot be aggregated. This is why we need to standardize this raw data to eliminate the bias of scale in the calculation of the composite indicator.

Table 2. Inventory results of Smart Economy's indicators

	Smart Innovation		Smart Productivity					
	Patent applications	Innovative cities ranking (out of 500 cities)	Number of HQ on Forbes 2000	GDP per capita 2014 (PPP, $)	Unemployment rate (persons of 15 years or more)	Global network integration towards world's network of cities	Ease of doing business - composite indicator (national level) (out of 190 countries)	IESE Economy performance ranking (out of 181 cities)
Mexico city	2403	84	11	19239	5.51 %	8	72.27	38
Rio de Janeiro	7208	130	4	14176	10.00 %	4	56.45	155
Buenos Aires	1142	60	0	23606	9.40 %	7	58.11	113
Bogota	751	224	1	17497	9 %	7	69.41	68
Santiago	940	172	6	23929	6.90 %	7	71.22	40
Lima	153	305	0	1653	6.60 %	6	69.45	84
Amsterdam	38908	12	13	45265	7.70 %	8	76.03	32

[4] For more details, see Freudenberg (2003).

We normalize the data with the Min-Max method: each indicator q for a city c is transformed in:

$$I_{qc} = \frac{X_{qc} - min(X_q)}{\max(X_q) - \min(X_q)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where min(x_q) and max(x_q) are the minimum and maximum values of x_q across all cities. Therefore, the normalized indicator I_{qc} has values lying between 0 (min(x_q)) and 1 (max(x_q)). For the indicators that are inversely proportional to city smartness, we adapt the Min-Max procedure in order to link positively the indicator value with city smartness (an increase in the value will increase smart city character). For instance, in the Smart Economy dimension, if the city has a high score in patent applications, it will increase its 'smartness score' while unemployment rate has an opposite impact (higher is the rate, less positive it is for the city's smartness). The approach has the advantage of being simple, but it has its fair share of limitations. For instance, the range is quite sensitive to the choice of cities. If any of the cities is performing poorly on an indicator and/or another really well, it will have an impact on the values produced by the approach. Indicators inversely proportional to city smartness are adapted with the following equation:

$$I'_{qc} = 100\% - \frac{X_{qc} - min(X_q)}{\max(X_q) - \min(X_q)} \ldots\ldots\ldots\ldots\ldots (3)$$

where I'_{qc} is the normalized indicator q of type « less is better ». Table 3 reports the results of the normalization process.

Table 3 Normalized values – Smart Economy

	Smart Innovation		Smart productivity					
	Patent applications	Innovative cities ranking (out of 500 cities)	Number of Headquarters on Forbes 2000	GDP per capita 2014 (PPP, $)	Unemployment rate (persons of 15y or more)	Global network integration towards world's network of cities	Ease of doing business - composite indicator (national level) (out of 190 countries)	IESE Economy performance ranking (out of 181 cities)
Mexico city	5.81%	75.43%	84.62%	40.32%	100.0%	100.0%	80.79%	95.12%
Rio de Janeiro	18.20%	59.73%	30.77%	28.72%	0.00%	0.00%	0.00%	0.00%
Buenos Aires	2.55%	83.62%	0.00%	50.34%	13.36%	75.00%	8.48%	34.15%
Bogota	1.54%	27.65%	7.69%	36.33%	22.27%	75.00%	66.19%	70.73%
Santiago	2.03%	45.39%	46.15%	51.08%	69.04%	75.00%	75.43%	93.51%
Lima	0.00%	0.00%	0.00%	0.00%	75.72%	50.00%	66.39%	57.72%
Amsterdam	100.0%	100.0%	100.0%	100.0%	51.22%	100.0%	100.0%	100.0%

The next step (step 3) is to compute the correlations between the basic indicators. These are reported in Table 4. It does so for each dimension computed in the first step. If it is low, it is unlikely that they share common determining factors. The marked values (**) in the correlation matrix are significant at the level of α = 0,05 (Pearson correlation test). This means that there should be a relatively large number of common parameters influencing their values. The method of Principal Component Analysis/Factor Analysis helps to reduce redundancy. For instance, as shown in table 4, the GDP per capita and the number of patent applications are significantly correlated, which means that a city with a higher number of patent applications will have generally a greater GDP per capita. Several economic studies highlighted indeed the importance of innovation in the GDP's growth process (OCDE, 2006) .

Table 4: Correlation Matrix (Pearson) of Smart Economy's indicators

	Patent applications	Innovative cities ranking	Number of HQ on Forbes 2000	GDP per capita 2014 (PPP. $)	Unemployment rate	Global network integration	Ease of doing business	IESE Economy performance ranking
Patent applications	1.000							
Innovative cities ranking	0.61	1.00						
Number of Headquarters on Forbes 2000	0.69	0.65	1.00					
GDP per capita 2014 (PPP. $)	**0.81****	**0.82****	0.70	1.00				
Unemployment rate	-0.032	-0.14	0.47	-0.06	1.0000			
Global network integration	0.29	0.38	0.50	0.57	0.5600	1.0000		
Ease of doing business	0.41	-0.02	0.60	0.37	0.7468	0.7299	1.0000	
IESE Economy performance ranking	0.32	0.13	0.61	0.47	0.7507	**0.8697****	**0.9482****	1.0000

The computation of the weighting factor for each indicators demanded by Step 4 is the most complex. The weights impact significantly the composite indicator value and hence, influence the city rankings results. Any solution will have winners and losers. The easiest option is the equal weighting method and consists in computing the mean of all indicators. However, giving all indicators equal weighting implies that there is no redundancy. It may happen that certain performance features will be overestimated by gathering variables with a high degree of correlation. To tackle this issue, indicators are tested for statistical correlations and their weights need to be balanced based on correlations. In this paper, a weighting set is computed from the principal component analysis (PCA) in order to reduce redundancy in the calculation of the composite indicator in each dimension.

The PCA transforms correlated indicators in a set of independent factors (principal components) while preserving the maximum proportion of the total variation in the data set (Nardo et al., 2005). It reduces the overlapping information between two or more variables. Formally, the analysis takes Q variables $x_1, x_2, \dots x_Q$ and finds linear combination of these to produce components $Z_1, Z_{2,} \dots Z_Q$ that are uncorrelated:

$Z_1 = a_{11}x_1 + a_{12}x_2 + \cdots + a_{1Q}x_Q$……………………………………

$Z_2 = a_{21}x_1 + a_{22}x_2 + \cdots + a_{2Q}x_Q$……………………………………(4)

…

$Z_Q = a_{Q1}x_1 + a_{Q2}x_2 + \cdots + a_{QQ}x_Q$

At this point there are still Q principal components (PC), i.e. as many as there are variables.

The weights a_{ij} (also called "factor loadings") of the PC applied to the variables x_j are chosen so that the principal components Z_i satisfy three conditions: (1) they are uncorrelated/orthogonal; (2) the first PC supports the maximum proportion of the variance, the second PC supports the maximum of the remaining variance and so on until the last of the principal components absorbs all the remaining variance not accounted by the preceding components, and (3) $a_{i1}^2 + a_{i2}^2 + \cdots + a_{iQ}^2 = 1, i = 1,2 \dots Q$ (Nardo et al. 2005). The eigenvalues of the indicators' correlation matrix are the variances of the PC and provide information on the variability in the data.

The decision on how many principal components should be retained in the analysis without losing too much information depends on the criteria ("stopping rules") selected. A criteria usually used to select and determine the number of components consists in: (1) having associated eigenvalues larger than one; (2) contributing individually to the explanation of overall variance by more than 10% and (3) contributing cumulatively to the explanation of the overall variance by more than 80% (Nardo et al., 2008). To illustrate the discussion, a PCA on Smart Economy is undertaken and, in light of the above analysis, the two first factors are retained. The results are reported in Table 5. The PCA is conducted with the R software (package FactoMineR).

Table 5: The PCA on the smart economy indicators

	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalues	4.452	2.221	0.586	0.491	0.113	0.037
% of var.	56.894 %	27.766 %	7.322 %	6.140 %	1.412 %	0.467 %
Cumulative % of var.	56.894 %	84.660 %	91.982 %	98.121%	99.533 %	100.000 %

After the extraction of the two first PC representing the data, we consider them as factors for the Factor Analysis. The following step consists in the rotation of factors' loadings. This step minimises the number of individual indicators that have a high loading on the same factor (Michela Nardo et al., 2005). It simplifies the structure of the factors and enhances the interpretability of the factors. Different rotational methods have been proposed and each of those strategies implies different meanings of principal components. However, the most commonly used is the "Varimax rotation" which is used in this study. The Varimax method is an orthogonal rotation minimizing the number of variables with high loadings on each factor The results are reported in Table 6.

Table 6: Factor loadings of the eight indicators of Smart Economy.
(extraction method: principal components, Varimax rotation)

	RC1	RC2
Patent applications	0.15	0.86
Innovative cities ranking	-0.07	0.91
Number of Headquarters on Forbes 2000	0.52	0.72
GDP per capita 2014 (PPP, $)	0.20	0.94
Unemployment rate	0.90	-0.17
Global network integration towards world's network of cities	0.78	0.37
Ease of doing business	0.94	0.18
IESE Economy performance ranking	0.95	0.24

The last step deals with the construction of the weighting coefficients for the Factors' loadings matric after Varimax rotation '*given that the square of factors depicts the proportion of the total unit variance of the indicator, which is explained by the factor*' (Nardo et al., 2005). We use the method proposed by Nicoletti et al. (2000): each factor loading is firstly squared, then, those with the highest value are selected and values are divided by the sum of the largest factor loadings. Therefore, the weighting coefficients for each indicator reported in Table 7 are the outcome of this procedure. .

Table 7 Weights for the Smart Economy's indicators. Extraction method: Principal components, Varimax rotation

Patent applications (PA)	0.120
Innovative cities ranking (IR)	0.134
# of HQ on Forbes 2000 (HQ)	0.084
GDP per capita 2014 (PPP, $) (GDP)	0.143
Unemployment rate (UR)	0.131
Global network integration towards world's network of cities (GN)	0.099
Ease of doing business (EDB)	0.143
IESE Economy performance ranking (IESE EP)	0.146
Total	**1.000**

Based on the results reported in Table 7, the composite indicator of smart Economy can be reduced to:

$$Smart\ Economy\ index = 0.120\ PA + 0.134\ IR + 0.084\ HQ + 0.143\ GDP$$
$$+0.131\ UR + 0.099\ GN + 0.143\ EEDB + 0.146\ IESE\ EP \quad (5)$$

Based on the value observed for each indicator for each city, we can know compute the degree of economic smartness for each city. The same procedure needs to be repeated for each of the other 5 smartness dimensions we have decided to include in our diagnostic (i.e. Smart Governance, Smart Education, Smart Living, Smart Environment and Smart Infrastructure). The detailed partial results for each are reported in the appendices.

The final step is the adoption of the same methodology to produce, for each city, a single indicator from these 6 partial indicators. This is what we will use to rank cities on their overall commitment to smartness in the management of their needs and constraints. This step and its results are the main focus of the next section.

4. Description of the data

Before discussing it may be useful to provide a brief explanation for the choice of cities and a brief overview of specific indicators used to approximate each dimension. The selection of cities was influenced by ongoing initiatives under way in Latin America. For example, Rio de Janeiro received the national title of the Smartest and Most Connected City of Brazil (Cohen, 2015). The city is trying to reinvent itself, exploiting new technologies for urban planning and bringing the government closer to the citizens (Schreiner, 2016). In parallel, the city launched the Rio Operations Centre in order to anticipate climatic events and thus, to reduce the burdens by alerting the citizens on time. The city's environment is also preserved, mostly by initiatives in the mobility system and in the public spaces management. In Mexico City, surveillance cameras have been installed for predictive analysis; the healthcare service has been improved by developing a system of healthcare information; an open data portal has been created and provides more than 1,000 datasets in several subjects; actions to engage citizens in the development of the knowledge society and in the management of public affairs are fostered and technology innovation to improve traffic flow and keep pollution under control are encouraged. In Buenos Aires, the city's environmental sustainability is implemented by considering energy efficiency aspects. The citizens' well-being is enhanced with the creation of the lighting management system CityTouch and the data platform SAP HANA. SmartCity Santiago, a high-tech integrated smart city pilot project, was designed to increase the inhabitants life quality by coordinating all kinds of technologies in an integrated, functional and safety way. Each one of these cities was thus natural candidate for this survey. Bogota and Lima were included because they are important capitals yet they do not receive as much coverage in the literature or in the media on the quality of their management as the larger cities of the region.

The choice of indicators is based on two criteria. The first was to try to rely as much as possible on the selection made by previous studies. We added various indicators when proxy choices were incomplete. The list contains 39 indicators. The second criterion was the availability of the data of the indicator chosen for each of the cities we wanted to cover in the analysis. This forced us sometimes to adjust the choice of specific indicators and it often made it impossible to do the same as the authors who had worked on Europe simply because there is less data available for developing and emerging economies on key indicators. For some indicators, we could not get data for the same year. For instance, the "Average years of schooling of inhabitants" varies between 2010 (for Rio de Janeiro) and 2015 (for Mexico City). Another issue is that many of the indicators are only available at the country level or for all urban populations. This means that for various dimensions, we need to assume that what holds for the country also holds for the city we are interested in.

In practice, this may have been the most frustrating part of this research. Data gaps have been so significant for the region that we were forced to work with much less information than what we had hope for and certainly than what theory and earlier efforts applied to Europe suggested we should have. Unfortunately, a considerable amount of available information on some cities is lost due to the removal of indicators with missing values on other cities. In the end, significantly fewer indicators were used than those covered in Appendix 1. And some dimensions are much better documented than others. For instance, for Smart Governance, only one indicator's data was collected compared to ten parameters in Smart Living. Therefore, Smart Governance presents a city with a score of 0% and another with a score of 100%, which is not reliable but is inherent to the Max-Min method. These limitations imply that the ranking produced can only be seen as a first order approximation, which will have to be improved upon once better data becomes available. It is imperfect, but it allows a first quantification of the various dimensions of smartness for emerging economies.

The rest of this section summarizes the details on the specific definitions, years of measurement and sources are provided in Appendix 1 while the specific values for each indicator are reported in Appendix 2 to ease any desire of replication. Since we already discussed the smart economy to illustrate the methodology, we will focus on the other dimensions.

Smart governance is approximated by only one indicator, the corruption perception index, which is only measured at national level. This is clearly a weak approximation but there is no real city specific measure available that allows comparable comparisons across cities in the region. It also an issue because it does not pick up the complexity of the interactions between cities and states/provinces and national authorities in a region in which many mandates are at least shared between the various levels of government. There is evidence for instance, that the lack of political alignment across government levels on shared mandates can be a major way in which governance drivers local ineffectiveness (Estache et al., 2016).

Smart Environment is a combination of three sub-dimensions. The first is Smart Environmental Quality, approximated by a combination of particulate matter (PM10) concentration, fine particulate matter (PM2.5) concentration, greenhouse gas emissions measured in tonnes per capita and green spaces per person. The second is Smart water approximated by water consumption. The last one is Smart Waste represented by a combination of the share of waste collected and adequately disposed and the waste generated per person. All of these measures are available at the city level. If more measures were available for all cities, it would not be too hard to add them, but as it stands with the indicators available the measure of environmental smartness to be reasonably well estimated.

Smart Human Capital reflects both quantity and quality variables but as in the case of governance, it needs to rely on national rather than city level data for most indicators. More specifically, the synthetic human capital indicator combines the number of universities in TOP 200 world ranking, the average years of schooling of inhabitants at city level, the adult illiteracy rate and the total public expenditure on education as a percentage of Gross Domestic Product. The fact that only some of the measures are at local level is a problem since it implies that any faults in the national system will be attributed also to the cities and this is not a systematic situation. A second issue with these indicators is that they are all quite highly correlated and the method adopted here will end up eliminating redundant information.

Smart Infrastructure combines smart mobility, smart utilities and smart ICT. Smart mobility is a combination of the length of mass transport network, road traffic deaths, the stock of cars and motorcycles (vehicles/person), the metro network length and the IESE Mobility performance ranking. Smart Utilities reflects the share of the population without sanitation, the share without drinking water and the share of households without electricity supply service. Smart ICT is approximated by the IESE Technology performance ranking which combines most of the relevant ICT variables. Once more, these measure are only available at the national level, imposing the now usual limitation if the correlation between the situation in the city analysed and the country is not high.

Smart living is the most heterogeneous measure. It accounts for smart culture (approximated by the number of museums), smart Tourism (approximated by the IESE International outreach ranking), smart Health (approximated by life expectancy of residents at birth), smart Safety (approximated by the number of crimes per 100,000 inhabitants), smart Poverty Management (approximated by the poverty ratio), smart jobs (approximated by average working hours per year of worker and domestic purchasing power (net annual income), smart Housing (approximated by the average rent prices for local households, and smart quality of Living (approximated by population density and a quality of living ranking). All of these variables are available at the city level making this indicator quite representative.

5. Discussion of the results

Table 8 reports the correlation between the various types of smartness. While it seems that except for environmental smartness, most of the other dimensions appear to be at least somewhat correlated with each other, even if from a strict statistical perspective, most of the correlations are not significant. Infrastructure and education are the only two dimensions with statistically significant correlation. This means that these are the only two dimensions for which there should be a relatively large number of common parameters influencing their values which is not unexpected since making the most of the opportunities offered by. For most of the other dimensions, when the correlation is high even if not statistically significant, there is reasons for concern as well if it is less likely to be an issue statistically.

Table 8: Correlation between smartness dimensions

	Smart Governance	Smart Economy	Smart Education	Smart Living	Smart Environment	Smart Infrastructure
Smart Governance	1.0000	0.4976	0.3918	0.6941	-0.0862	0.4323
Smart Economy	0.4976	1.0000	0.6511	0.4656	0.0416	0.6361
Smart Education	0.3918	0.6511	1.0000	0.5068	-0.0841	0.7912**
Smart Living	0.6941	0.4656	0.5068	1.0000	-0.3650	0.2762
Smart Environment	-0.0862	0.0416	-0.0841	-0.3650	1.0000	0.5159
Smart Infrastructure	0.4323	0.6361	0.7912**	0.2762	0.5159	1.0000

** Significantly correlated at p=0.05

The PCA and the factor analysis step are used to reduce the risks of redundancies as discussed earlier. The PCA identifies 5 factors for the final single score. Only the first 2 seem to matter as they jointly explain 78% of the cumulative variance (which is close to the 80% rule of thumb discussed in the methodology). The others are hence ignored in the following steps. Once the factor loadings for each dimension have been measured, the weights to be used in the aggregation can be computed. These are reported in Table 9 along with the results of the full ranking diagnostic.

To get a full sense of the policy relevance of the results and the usefulness of the approach, the table needs to be read in four ways. The first is to focus on the last column, which reports the ranking of cities based on the synthetic composite indicator accounting for all weighted dimensions jointly. The second useful way of reading the table is to look at the ranking in terms of each dimensions of smartness individually. This second approach shows that none of the Latin American cities is a top performer on every dimension. The third way is to look at the relative performance of each dimensions overall. The final main way of reading the table is horizontally because it allows for any given city the identification of weak spots in terms of specific dimensions. Some cities can be best performers on some dimensions while be poor performers on others, pointing the areas on which improvement are needed. On any dimension for which the score is 100%, it means that the city is the best performer. Moving close to 0% instead, indicates that the city is a poor performer. To make the table easier to read, for each dimension, the best and worst performances are highlighted respectively in dark and light grey.

Table 9: Overall score								
	Smart Governance	Smart Economy	Smart Education	Smart Living	Smart Environment	Smart Infrastructure	Weighted final score	Ranking
Dimensions Weights	0.141	0.173	0.181	0.137	0.212	0.156		
Mexico city	0.000%	72.121%	75.906%	31.583%	72.059%	73.218%	**57.241%**	**3rd**
Rio de Janeiro	38.261%	16.884%	33.311%	41.135%	74.224%	58.948%	**44.912%**	**6th**
Buenos Aires	24.348%	34.073%	**92.389%**	50.979%	57.090%	69.320%	**55.951%**	**4th**
Bogota	28.696%	39.856%	34.306%	30.981%	**84.852%**	64.225%	**49.403%**	**5th**
Santiago	86.087%	58.421%	78.812%	42.362%	57.509%	71.227%	**65.617%**	**2nd**
Lima	19.130%	32.795%	25.225%	43.622%	40.617%	32.258%	**32.556%**	**7th**
Amsterdam	**100.000%**	**93.593%**	89.094%	**70.736%**	64.193%	**79.434%**	**82.109%**	**1st**

The first reading of the table, focusing on the final score, confirms that Amsterdam is well ahead of the Latin American cities of the sample in terms of smartness overall. Amsterdam enjoys a final score of 82.1% while Santiago is only at 65.6%. Lima is the worst performer with a score of 32.6%. While Amsterdam still has some margin to improve, what stands out from a Latin American perspective based on the indicators adopted here, is that the margin is significantly lower than the margin identified for the best performing Latin American country. It is also striking to note the divergence of margins for improvements in the region across countries. The efforts that Lima, Rio de Janeiro or Bogota have to make to catch up are significant larger than what Santiago has to do for instance. It is also striking to see how much Mexico City is penalized by its poor governance score. On almost every other dimension, it performs quite well. But it lags too significantly all of the other cities in terms of governance to be seen as fitting into the "smart" performers.

The second reading of the table, focusing on the performance with respect to individual dimensions, shows that, on two such dimensions, smart environment and smart education, some Latin American cities do better than Amsterdam. Buenos Aires has a smarter education performance than Amsterdam. This result on smart education is influenced the single indicator available, the total expenditure of education (weighting factor 0.284) where Amsterdam has a low score. This indicator is actually also affecting significantly the results for Smart Education in the IESE Economy ranking. Bogota, Mexico City and Rio de Janeiro do better than Amsterdam in terms of environmental smartness for the indicators used to approximate this dimension in this paper (greenhouse gas (GHG) emissions per capita (weighting factor 0.173)). On both dimensions, better data could maybe lead to different conclusions and this illustrates the scope there is for disagreement based on the specific choice of proxies for each dimensions. It also illustrates the cost imposed by a poor monitoring of key city management dimensions. Poor data means poor manipulable accountability.

The third reading suggests that the main hurdles for the region remain primarily in Smart Living (across the region) and Smart Governance (except for Santiago) when compared to Amsterdam scores. We have already established that the governance indicator we are relying on is quite incomplete. But it does seem to be unreasonable to argue that any measure of governance in the cities of the region would significantly lag the Dutch benchmark. Most of the countries are still young democracies in politically complex contexts with imperfect implementations of decentralization with blurred mandates assigned to cities in most of the dimensions of smartness. The significant lag observed for the living standards smartness is not surprising either. But it adds some general information. Any effort to become more exhaustive and to account for more core indicators may add to the gap rather than help the cities compared to benchmark look better (smart living benefits from the largest number of indicators). Note that the performance on the economy and infrastructure smartness is less critical for the Latin American situation. Some of the cities actually do quite well on these dimensions.

Finally, the table allows a rough diagnostic of the main challenges each city faces. This is of course influenced by the specific indicators choices and it would have to be adjusted by a much more precise diagnostic to be conducted at the local level. But it offers the city managers a chance to see how the external observers perceive their performance in terms of smart management.

Santiago with an overall score of 65.617% is the best city in our ranking even though it does not have the highest score in any dimension. The city performs well in Smart Governance, due to his Corruption Perception Index rank. Regarding Smart Economy, the city is above the average; it has a positive performance in the IESE Economy performance ranking while it has to improve its innovation's level by increasing its patent applications. For Smart Education, the city has a good score in adult illiteracy rate but it is balanced with a low share of education expenditures. Concerning Smart Living, whereas the city has high life expectancy, it still has to enhance its Smart Culture and Smart Tourism. Despite its effort to assure clean air, its average score in Smart Environment is still low. The city scored well in Smart Infrastructure mainly thanks to its developments in transportation and in utilities, even though it has the lowest rating in the IESE Technology performance.

Ranked third, Mexico City is successful in Smart Education as well as in Smart Economy by dint of the number of companies' headquarters, unemployment rate, global network integration, ease of doing business and IESE Economy performance rank. However, Mexico City presents the lowest rating for Smart Governance (the administration of president Enrique Peña Nieto was accused of political corruption in 2016; Agren, 2017) and has a weak score for Smart Living. This is explained by bad results in life expectancy, poverty ratio, average working hours per worker, domestic purchasing power and quality of living rank. Regarding Smart Environment and Infrastructure, the city is above the average.

Buenos Aires performs the best score in terms of Smart Education and has good results in Smart Living by means of its number of museums and quality of life rank. However, the city has to improve in Smart Governance, Smart Environment (green space per person sufficiently low, water consumption and waste generated rather high) and Smart Infrastructure (significant stock of cars).

Ranking fifth, Bogota is significantly below the average for Smart Governance (recent investigations suggests that the president's re-election campaign accepted dirty money; Diaz ,2017), as well as for Smart Economy (Smart Innovation relatively low), Smart Education (lowest average years of schooling) and Smart Living (low score in Smart Culture, Tourism, Health, Safety and quality of living). However, the city is the best in terms of Smart

Environment largely explained by green space availability, water consumption and waste production.

Rio de Janeiro is ranked only at the 6th position. This is not consistent with the awards received and mentioned earlier. The city needs to improve the smartness of its economy. It has the lowest rate for each indicator in Smart Productivity and it still has the lowed score in Smart Education with the highest illiteracy rate. It also suffers from a poor performance in terms of Living (lowest Smart Health and Safety) and Infrastructure dimensions. Nevertheless, the city over-performs in Smart Environment, influenced by the presence of a forest (Tijuca) in the city.

Lima, the worst performing city in our ranking**,** has an overall score of 32.556%. This result is not surprising since the city presents the highest number of lowest scores for all dimensions. It is also consistent with the fact that increasingly the smartness of the city has not yet appeared on the local political agenda and media coverage.

6. How technologically smart are all dimensions?

Considering that many observers of the debates on city smartness continue to emphasize the role of ICT in defining the overall management quality of cities, it seems useful to try to get a rough sense of the interaction between the technological characterization of cities and the other dimensions we used to measure their overall smartness. This is done by computing the correlation between "smart ICT" and all of the other main dimensions. In addition, we unbundled the infrastructure dimension and report the correlation between ICT on the one hand and mobility and utilities on the other hand. The results are reported in Table 10.

Table 10: How does ICT smartness correlate with other dimensions of smartness?

	Pearson correlation coefficient (** significant at 10%)
Smart Governance	0,360
Smart Economy	**0,711****
Smart Education	0,563
Smart Living	**0,704****
Smart Environment	0,203
Smart Mobility	-0,444
Smart Utilities	0,477
Smart ICT	1,000

The first insight provided by the table is that the degree of significance had to be computed at the 10% level, because none of the correlations were significant at the 5% level. This can be interpreted in two somewhat contradictory ways. The first is that ICT is underused in management since the correlation is weak. The second is that the correlation is weak because there is much more to smart management than simply increasing the role of ICT in the overall management of the cities. Both explanations are realistic but a more precise analytical treatment of the data is needed to identify the right one.

Downgrading the expected significance of the correlation to 10% reveals a partial positive correlation between smart ICT and smart economy and living. The high and significant correlation between ICT and the economic performance is not too surprising since some of the indicators characterizing the economic smartness of a city are routinely related to ICT (e.g.

ease of doing business or innovative capacity). The correlation with smart living is somewhat less expected since smart living covers many indicators more concerned with human dimensions of city living. The correlation is likely to be driven by jobs and housing. But there may be more to this insight that also needs to be tracked down through a more thorough diagnostic. Finally, the lack of correlation, even at the 10% level with other infrastructure dimensions of city management may also be a matter of concern. In most advanced economies, it is quite common to argue that the future of utilities and mobility are connected to the increased use of ICT in the monitoring of both supply and demand. This is apparently not happening yet in Latin America.

Overall, this simple correlation analysis highlights the relevance of the importance of the concept of smartness in the assessment of the overall city management quality. ICT is indeed offering useful opportunities to become smarter in some dimensions. But there are also some dimensions on which the correlation is unlikely to be high, simply because there is much more to sound city management than simply betting on ICT to solve all problems.

7. Conclusions

Despite its limitations, the analysis reported in this paper provides enough evidence suggesting that Latin American cities still have a long way to go to get to “smartness”. Clearly, a more thorough diagnostic is needed at the city level to complement and validate or reject some of the conclusions. But it seems that the information available is good enough to shift the burden of proof on the city managers. The analysis identifies quite clearly some dimensions on which each city needs to focus on to be able to make the most of the resources it enjoys and achieve what international best practice define as smart city management.

In some cases, these dimensions are a problem for all Latin American cities. More specifically, the region is particularly weak in meeting the multiple requirements of Smart Living and the single measure of Smart Governance may indeed be the main challenges in the region across cities. On the other hand, most, although not all, do quite well on other dimensions, notably the indicators defining Smart Environment and Smart Infrastructure for which the emphasis on digitalization placed by managers concerned has been paying off. But this emphasis has not impacted most of the other dimensions of smartness.

From a policy perspective, two clear insights emerge from the analysis. The first, a possibly the most obvious one is that a lot does not get done probably because it is not measured. The scarce data availability at the city level is symptomatic of lack of commitment to transparency and hence of a concern for accountability city managers share with national managers in a region with a well-documented corruption and political instability problem. The recent Odebrecht scandal has impacted many national politicians but for decisions with a direct impact on many of the largest cities of the region, including those covered by the sample analysed in this paper. The second insight is that many of the indicators for which cities seem to be weak are not under the direct control of city managers. For many of the decisions that would strengthen these dimensions, the local authorities need to be able to work with national or provincial/state authorities as in shared mandates are quite common in the region.

From a more general perspective, the paper has demonstrated that there could be a payoff to work with the approach suggested to conduct a more general diagnostic of Latin American cities. This has already been recognized by various consulting firms, The next step is to make the information more transparent and less subjective to stimulate accountability and allow all stakeholders to access the information and come up with ideas to close the gaps. It would also a much more realistic assessment of the scope and limits of ICT as a driver of city smartness, considering the multiplicity of concerns city managers need to account for.

It would seem useful for the region to conduct the analysis on a much more representative sample than the one we relied on to illustrate the potential of the approach. And since international databases are likely to be constraining in the short run, an alternative would be to conduct national benchmarks to make the most of the abilities of each countries to mobilise local information even if it does not fully match some international standards. National city benchmarking exercises should be just as useful as international ones if they can be used to identify gaps and to put in place performance improvements monitoring systems. And ultimately, it all boils down to making cities smarter than they are today on each of the dimensions discussed here. How well and how fast this done is eventually going to be a local challenge within each country. So why not start with a few national benchmarks of multiple cities for a few countries based on a common regional methodology?

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8. Appendices

Appendix 1: Indicators description and sources

Dimension	Factor	Indicator	Description	Unit	Level	City	Year	Data Source
Smart Economy	Smart Innovation	Patent applications		# of patents	National	ALL	2017	World Intellectual Property Organisation
		Innovative cities ranking	Out of 500 cities	-	Local	ALL	2017	Innovation Cities Program
		Number of headquarters on Forbes 2000		# of HQ	Local	ALL	-	Forbes 2000
		Gross Domestic Product per capita 2014 (PPP, $)		$/capita 2014 PPPs	Local	ALL	2014	Brookings, *Global metro monitor*
	Smart Productivity	Unemployment rate	Of persons of 15 years or more unemployed	%	Local	Mexico City	2016	Instituto Nacional de Estadística y Geografía (INEGI)
						Rio de Janeiro	2015	Instituo Brasileiro de Geografia e Estatística (IBGE)
						Buenos Aires	2017	El Cronista, "Bajo el desempleo a 8,7% en el segundo semestre por la menor búsqueda de trabajo" (2017)
						Bogota	2016	Departamento Administrativo Nacional de Estadística (DANE) ; Comisión Económica para América Latina y el Caribe (CEPAL) ; World Bank
						Santiago	2015	CASEN, Ministerio de Desarrollo Social, Subsecretaria de Evaluación Social 2015 "*trabajo Síntesis de Resultados*" (2017)
						Lima	2017	Peru Telegraph, *« Average wage and unemployment rate in Lima »* (2017) (INEI Employment Report No. 6, June 2017) https://www.perutelegraph.com/news/peruvian-economy/average-wage-and-unemployment-rate-in-lima-2017"
						Amsterdam	2015	Centraal bureau voor de statistiek
		Global network	How integrated the city is into the world's network of cities	From Alpha+ + = 10 (to) to 0 bottom	Local	ALL	2016	The World According to GaWC 2016
		Ease of doing business	Out of 190 countries - composite indicator	-	National	ALL	2016	Doing Business database
		IESE Economy performance ranking	Out of 181 cities – composite indicator: productivity, time to start a business, ease of starting business, number of headquarters, % people at early business stage, entrepreneurs, GDP	-	Local	ALL	2017	IESE Business School
Smart Governance		Corruption perception index rank	Out of 176 countries	-	National	ALL	2016	Transparency National
Smart Environment	Smart Environmental Quality	Particulate matter (PM10) concentration		ug/m3	Local	ALL	2011-2016	WHO, Ambiant Air Pollution Data base, 2014
		Fine particulate matter (PM2.5) concentration		ug/m3	Local	ALL	2011-2016	WHO, Ambiant Air Pollution Data base, 2014

		Greenhouse gas emissions measured in tonnes per capita		Tonnes / capita	Local	Mexico City	2008	United Nations Human Settlement Programme, Global Urban Indicators Database (2015)
						Rio de Janeiro	2007	Data Rio
						Buenos Aires	2011	International Institute for Environment and Development, *Greenhouse gases: Rich cities, not big cities, are main culprits* (2011) http://www.citymayors.com/environment/greenhouse_gas.html#Anchor-Per-49575
						Bogota	2012	C40 Cities
						Santiago	2008	United Nations Human Settlement Programme (UN-Habitat), Global Urban Indicators Database 2015
						Lima	2012	WHO Outdoor Air Pollution Database
						Amsterdam	2007	Green Capital Award Application (CO2 emissions); Dienst Onderzoek (population).
		Green spaces per person		m2/person	Local	ALL	2007-2009	Economist Intelligence Unit "*Latin American Green City Index - Assessing the environmental performance of Latin America's major cities"*, sponsored by Siemens Global Website (2010); For Amsterdam: GreenSurge "*Amsterdam, the Netherlands Case Study City Portrait"* (2015)
	Smart Water	Water consumption		Litres/person/day	Local	ALL	2008-2014	Economist Intelligence Unit "*Latin American Green City Index - Assessing the environmental performance of Latin America's major cities"*, sponsored by Siemens Global Website (2010); Amsterdam: Water statistics for capitals in 2010-2014
	Smart Waste	Share of waste collected and adequately disposed		%	Local	ALL	2008-2016	Economist Intelligence Unit "*Latin American Green City Index - Assessing the environmental performance of Latin America's major cities"*, sponsored by Siemens Global Website (2010); Amsterdam: Assumption
		Waste generated per person		kg/person/year	Local	ALL	2007-2010	Economist Intelligence Unit "*Latin American Green City Index - Assessing the environmental performance of Latin America's major cities"*, sponsored by Siemens Global Website (2010); Amsterdam: European Environment Agency

Smart Human Capital		Number of universities in TOP 200 world ranking		# Universities	Local	ALL	2016	QS Ranking
		Average years of schooling of inhabitants	Population of 5 years and over	Years	Local	Mexico City	2015	Instituto Nacional de Estadística y Geografía (INEGI), *Encuesta Intercensal* (2015)
						Rio de Janeiro	2010	Instituo Brasileiro de Geografia e Estatística (IBGE) *Demographic Census* (2010)
						Buenos Aires	2014	Dirección General de Estadística y Censos (Ministerio de Hacienda GCBA). EAH 2014.
						Bogota	2011	Republica de Colombia Ministerio de Educación Nacional Plan Sectorial de la Revolución educativa
						Santiago	2015	CASEN 2015 Ministerio de Desarrollo Social, Subsecretaria de Evaluación Social *"educación síntesis de resultados"* (2016) http://observatorio.ministeriodesarrollosocial.gob.cl/casen-multidimensional/casen/docs/CASEN_2015_Resultados_educacion.pdf
						Lima	2011	Instituto Nacional de Estadística e Informática - Encuesta Nacional de Hogares.
						Amsterdam	2016	United Nations Development Program
		Quality of education: adult illiteracy rate	% Population of 15 years or more illiterate	%	Local	Mexico City	2015	Instituto Nacional de Estadística y Geografía (INEGI) *Encuesta Intercensal* (2015)
						Rio de Janeiro	2015	Instituo Brasileiro de Geografia e Estatística (IBGE)
						Buenos Aires	2010	INDEC. Censo Nacional de Población, Hogares y Viviendas 2010. Instituto Geográfico Nacional (IGN) http://www.sig.indec.gov.ar/censo2010/

						Bogota	2011	Republica de Colombia Ministerio de Educación Nacional Plan Sectorial de la Revolución educativa - Programa Nacional de Alfabetización y Educación Básica de Jóvenes y Adultos
						Santiago	2007	Encuesta CASEN, Ministerio de Planificación (MIDEPLAN) 2007.
						Lima	2014	Instituto Nacional de Estadística e Informática - Encuesta Nacional de Hogares.
						Amsterdam	2015	Knoema
		Total public expenditure on education as a percentage of Gross Domestic Product		%	National	ALL	2013	UNESDOC/UNESCO

Smart Infrastructure	Smart Mobility	Length of mass transport network		km/km2	Local	ALL	2007-2009	Economist Intelligence Unit "*Latin American Green City Index - Assessing the environmental performance of Latin America's major cities"*, sponsored by Siemens Global Website (2010); Amsterdam: Green Capital Award Application
		Road traffic deaths		Number of traffic deaths	National	Mexico City	2012	Instituto Nacional de Estadística y Geografía (INEGI)
						Rio de Janeiro	2013	Mortality Information System (SIM).
						Buenos Aires	2013	National Direction of Road Safety Observatory, ANSV
						Bogota	2013	National Institute of Legal Medicine and Forensic Sciences
						Santiago	2013	Integrated Statistical System of Chilean Police (SIEC2).
						Lima	2013	Peruvian National Police
						Amsterdam	2016	Statistics Netherlands - Trends in the Netherlands 2016
		Stock of cars and motorcycles		Vehicles /person	Local	ALL	2007-2017	Economist Intelligence Unit "*Latin American Green City Index - Assessing the environmental performance of Latin America's major cities"*, sponsored by Siemens Global Website (2010); Amsterdam; Siemens Global Website "European Green City Index" (2009)
		Metro network length		km	Local	ALL	2007	World Metro Database
		IESE Mobility performance ranking	Out of 181 cities - traffic index, inefficiency index, # road accidents, metro, flights, means of transportation, index of traffic for commuting to work	-	Local	ALL	2017	IESE Business School
	Smart Utilities	Population without sanitation	Open defecation + unimproved sanitation	%	Urban	ALL	2015	WHO/ UNICEF *Joint Monitoring program for water supply and sanitation - Progress on Drinking Water, Sanitation and Hygiene* (2017)
		Population without drinking water	Surface water + unimproved water	%	Urban	ALL	2015	WHO/ UNICEF *Joint Monitoring program for water supply and sanitation - Progress on Drinking Water, Sanitation and Hygiene* (2017)
		% Households without electricity supply service		%	Local	Mexico City	2015	CONEVAL con base en el XII Censo de Población y Vivienda 2000, II Conteo de Población y Vivienda 2005, Censo de Población y Vivienda 2010 y Encuesta Intercensal 2015
						Rio de Janeiro	2015	Instituo Brasileiro de Geografia e Estatística (IBGE)
						Buenos Aires	2010	INDEC. Censo Nacional de Población, Hogares y Viviendas 2010.
						Bogota	2014	Secretaria de Planeación

						Santiago	2015	CASEN 2015 "vivienda y entorno Síntesis de Resultados" Ministerio de Desarrollo Social, Subsecretaria de Evaluación Social 20 de Noviembre de 2016
						Lima	2012	UN Habitat 2016 cities - United Nations Human Settlement Programme, Global Urban Indicators Database 2015
						Amsterdam	2015	World bank data
	Smart ICT	IESE Technology performance ranking	Out of 181 cities - Number of broadband subscribers, broadband, IP addresses, Facebook, mobile phones, quality of web services, innovation index, smartphones, Wi-Fi hotspots	-	Local	ALL	2017	IESE Business School

Smart Living	Smart Culture	Number of museums		# of museums	Local	Mexico City	2007	Sistema de información cultural
						Rio de Janeiro	2010	CADASTRO NACIONAL DE MUSEUS - IBRAM / MINC, 2010
						Buenos Aires	2014	Guía de Museos de Buenos Aires
						Bogota	2013	Subdirección de Análisis Sectoriales, Poblacional y Local. Secretaría de Cultura, Recreación y Deporte.
						Santiago	2016	Registro Museos Chile
						Lima	2013	Guía de Museos del Perú - Ministerio de Cultura
						Amsterdam	2016	WhichMuseum, *"Musea in Amsterdam"*, https://whichmuseum.nl/nederland/amsterdam/musea
	Smart Tourism	IESE International outreach ranking	Out of 181 cities – composite indicator: Number of international tourists, number of passengers of an airline, hotels, sights map, number of conferences and meetings	-	Local	ALL	2017	IESE Business School
	Smart Health	Life expectancy of residents at birth		Years	Local	Mexico City	2016	Instituto Nacional de Estadística y Geografía (INEGI), *Encuesta Intercensal* (2015)
						Rio de Janeiro	2015	Instituo Brasileiro de Geografia e Estatística (IBGE)
						Buenos Aires	2010	INDEC. Censo Nacional de Población, Hogares y Viviendas 2010. Instituto Geográfico Nacional (IGN) http://www.sig.indec.gov.ar/censo2010/
						Bogota	2015	Secretaria Distrital de Planeación
						Santiago	2015	Gonzalo Haristoy "¿Cuál es la esperanza de vida en Santiago?" (2015) https://www.civico.com/santiago/noticias/cual-es-la-esperanza-de-vida-en-santiago
						Lima	2015	Instituto Nacional de Estadística e Informática (INEI) - Esperanza de Vida al Nacer https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib0015/cap-59.htm
						Amsterdam	2014	Volksgezondheidenzorg.info https://www.volksgezondheidenzorg.info/echi-indicators/mortality#!node-life-expectancy
	Smart Safety	Number of crimes per 100,000 inhabitants		# Crimes per 100,000 inhabitants	Local	ALL	2015	IGARAPE Homicide Monitor
	Smart Poverty Management	Poverty ratio		%	Local	Mexico City	2016	Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL), Medición de la Pobreza 2008-2016
						Rio de Janeiro	2007	Instituo Brasileiro de Geografia e Estatística (IBGE)
						Buenos Aires	2017	Condiciones de vida en la Ciudad de Buenos Aires: Incidencia de la indigencia y de la pobreza y estratificación. 4to. Trimestre de 2016 http://www.estadisticaciudad.gob.ar/eyc/wp-content/uploads/2017/05/ir_2017_1138.pdf

						Bogota	2016	Departamento Administrativo Nacional de Estadística (DANE)
						Santiago	2015	CASEN 2015 ministerio de desarrollo social, subsecretaria de evaluación social, "*situación de la pobreza en chile*" (2016)
						Lima	2016	Instituto Nacional de Estadística e Informática - Encuesta Nacional de Hogares.
						Amsterdam	2014	The Netherlands institute for social research; *Poverty on the Cards 2016* (2016) (poverty line in 2014 = €971 per month for a single person)
	Smart Jobs	Average working hours per year of worker		Hours/ year/ work	Local	ALL	2015	UBS Price and Earnings 2015
		Domestic purchasing power (net annual income)		US dollars	Local	ALL	2015	UBS Price and Earnings 2015
	Smart Housing	Values for average rent prices (monthly gross rents) for local households (normal local rent)		US dollars	Local	ALL	2015	UBS Price and Earnings 2015
	Smart Quality of Living	Population density		Person/ km2	Local	ALL	2009	Economist Intelligence Unit, *Latin American Green City Index "Assessing the environmental performance of Latin America's major cities*" sponsored by Siemens Global Website (2010)
		Quality of living ranking	Out of 231 cities - *	-	Local	ALL	2017	Mercer Quality of Living Survey (2017)

* Political and social environment (political stability, crime, law enforcement)
Economic environment (currency-exchange regulations, banking services)
Socio-cultural environment (media availability and censorship, limitations on personal freedom)
Medical and health considerations (medical supplies and services, infectious diseases, sewage, waste disposal, air pollution)
Schools and education (standards and availability of international schools)
Recreation (restaurants, theatres, cinemas, sports and leisure)
Consumer goods (availability of food/daily consumption items, cars)
Housing (rental housing, household appliances, furniture, maintenance services)
Natural environment (climate, record of natural disasters)

Appendix 2: Basic indicators values

Appendix table 2.1 Inventory results for Smart Governance indicators

	Corruption perception index (national level) rank (out of 176 countries)
Mexico city	123
Rio de Janeiro	79
Buenos Aires	95
Bogota	90
Santiago	24
Lima	101
Amsterdam	8

Appendix table 2.3 Inventory results for Smart Education indicators

	Number of universities in Top 200 worldwide	Average years of schooling	Quality of education: adult illiteracy rate	Total public expenditure on education as a % of GDP
Mexico city	1	11.12	1.48 %	5.15
Rio de Janeiro	0	10.03	4.23 %	5.82
Buenos Aires	1	12.50	0.50 %	5.14
Bogota	0	9.40	1.60 %	4.93
Santiago	1	11.60	0.50 %	4.55
Lima	0	11.00	2.10 %	3.28
Amsterdam	1	11.90	1.00 %	5.53

Appendix table 2.4 Inventory results for Smart Living indicators

	Smart Culture	Smart Tourism	Smart Health	Smart Safety	Smart Poverty Management	Smart Jobs		Smart Housing	Smart Quality of living	
	Number of museums	IESE International outreach ranking (out of 181 cities)	Life expectancy of residents at birth	Number of crimes per 100,000 inhabitants	Poverty ratio	Average working hours per year of worker	Domestic purchasing power (net annual income)	Values for average rent prices (monthly gross rents) for local households (normal local rent)	Population density	Quality of living ranking (out of 231 cities)
Mexico city	148	56	76.20	9.60	27.60 %	2260.90	29.1	770	5954.2	128
Rio de Janeiro	124	60	75.90	21.00	23.85 %	1745.50	49.4	590	5234.1	118
Buenos Aires	162	47	77.20	5.10	18.90 %	1899.40	38.4	710	15013.4	93
Bogota	46	86	75.94	17.20	11.60 %	2096.30	42.9	380	4087.7	129
Santiago	53	71	83.50	8.10	20.10 %	2081.60	53.6	710	10920.7	95
Lima	70	64	79.00	5.00	11.00 %	1956.80	38.4	800	2982.2	124
Amsterdam	83	7	78.80	1.50	14.40 %	1726.00	76.3	1220	4908.0	12

Appendix table 2.5 Inventory results for Smart Environment indicators

	Smart Environmental Quality				Smart Water	Smart Waste	
	Particulate matter (PM10) concentration	Fine particulate matter (PM2.5) concentration	Greenhouse gas emissions	Green space per person	Water consumption	Share of waste collected and adequately disposed	Waste generated per person
Mexico city	42	20	3.4	28.40	178.00	100.00 %	489
Rio de Janeiro	49	16	2.17	58.00	301.30	98.60 %	525.2
Buenos Aires	26	14	3.83	6.10	669.20	100.00 %	606.1
Bogota	52	24	3.4	107.30	114.30	99.70 %	289.8
Santiago	64	29	3.42	26.10	243.00	98.90 %	563.1
Lima	88	48	2.6	2.00	151.50	78.10 %	314.2
Amsterdam	25	18	6.66	17.62	136.00	100.00 %	487.07

Appendix table 2.6 Inventory results for Smart Infrastructure indicators

	Smart Mobility					Smart Utilities			Smart ICT
	Length of mass transport network	Number of deaths in traffic accidents	Stock of cars and motorcycles	Metro network length	IESE Mobility performance ranking (out of 181 cities)	% Households without sanitation	% Households without drinking water	% Households without electricity supply service	IESE Technology performance ranking (out of 181 cities)
Mexico city	5.60	17653	0.40	201.1	33	2 %	0 %	0.05 %	73
Rio de Janeiro	8.60	42291	0.26	55.5	43	8 %	1 %	0.02 %	102
Buenos Aires	7.00	5209	0.66	53.9	49	1 %	0 %	0.21 %	82
Bogota	6.90	6.219	0.15	0.0	154	2 %	0 %	0.10 %	104
Santiago	5.10	1623	0.14	102.4	91	0 %	0 %	0.10 %	129
Lima	5.20	3110	0.14	34.4	118	8 %	5 %	0.70 %	124
Amsterdam	3.24	629	0.41	42.5	20	0 %	0 %	0.00 %	6

Appendix 3: Composite single score index

Appendix table 3.1.1 Normalised values of Smart Governance indicators

	Corruption perception index (national level) rank (out of 176 countries)
Mexico city	0.000%
Rio de Janeiro	38.261%
Buenos Aires	24.348%
Bogota	28.696%
Santiago	86.087%
Lima	19.130%
Amsterdam	100.000%

As there is only one indicator in this dimension, the weight given to the indicator is 1.

Appendix table 3.3.1 Normalised values of Smart Education indicators

	Number of universities in Top 200 worldwide	Average years of schooling	Quality of education: adult illiteracy rate	Total public expenditure on education as a % of GDP
Mexico city	100.000%	55.484%	73.727%	73.622%
Rio de Janeiro	0.000%	20.323%	0.000%	100.000%
Buenos Aires	100.000%	100.000%	100.000%	73.228%
Bogota	0.000%	0.000%	70.509%	64.961%
Santiago	100.000%	70.968%	100.000%	50.000%
Lima	0.000%	51.613%	57.105%	0.000%
Amsterdam	100.000%	80.645%	86.595%	88.583%

Appendix table 3.3.2 Correlation matrix of Smart Education indicators

	Number of universities in Top 200 worldwide	**Average years of schooling**	**Quality of education: adult illiteracy rate**	**Total public expenditure on education as a % of GDP**
Number of universities in Top 200 worldwide	**1.0000**	0.8163**	0.7359	0.2686
Average years of schooling	0.8163**	**1.0000**	0.6558	-0.0378
Quality of education: adult illiteracy rate	0.7359	0.6558	**1.0000**	-0.2063
Total public expenditure on education as a % of GDP	0.2686	-0.0378	-0.2063	**1.0000**

** Significatively correlated at p=0.05

Appendix table 3.3.3 Principal components (PCA – FactoMineR) – Smart Education

	PC1	**PC2**	**PC3**	**PC4**
Eigenvalues	2.474	1.130	0.323	0.073
% of var.	61.86 %	28.24 %	8.08 %	1.82 %
Cumulative % of var.	61.86 %	90.10 %	98.18 %	100.00 %

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Appendix table 3.3.4 Factor loadings of Smart Education's indicators.
Extraction method: principal components, varimax rotation

	RC1	**RC2**
Number of universities in Top 200 worldwide	0.93	0.29
Average years of schooling	0.91	-0.01
Quality of education: adult illiteracy rate	0.88	-0.25
Total public expenditure on education as a % of GDP	0.00	0.99

Appendix table 3.3.5 Weights for the Smart Education's indicators.
Extraction method: Principal components, varimax rotation

Number of universities in Top 200 worldwide	0.251
Average years of schooling	0.240
Quality of education: adult illiteracy rate	0.225
Total public expenditure on education as a % of GDP	0.284
Total	**1.000**

Appendix table 3.4.1 Normalised values of Smart Living indicators

	Smart Culture	Smart Tourism	Smart Health	Smart Safety	Smart Poverty Management	Smart Jobs		Smart Housing	Smart Quality of Living	
	Number of museums	IESE International outreach ranking (out of 181 cities)	Life expectancy of residents at birth	Number of crimes per 100.000 inhabitants	Poverty ratio	Average working hours per year of worker	Domestic purchasing power (net annual income)	Values for average rent prices	Population density	Quality of living ranking (out of 231 cities)
Mexico city	87.931%	37.97%	3.947%	58.462%	0.000%	0.000%	0.000%	53.571%	75.298%	0.855%
Rio de Janeiro	67.241%	32.91%	0.000%	0.000%	22.590%	96.354%	43.008%	75.000%	81.283%	9.402%
Buenos Aires	100.000%	49.37%	17.105%	81.538%	52.410%	67.583%	19.703%	60.714%	0.000%	30.769%
Bogota	0.000%	0.00%	0.526%	19.487%	96.386%	30.772%	29.237%	100.000%	90.811%	0.000%
Santiago	6.034%	18.99%	100.000%	66.154%	45.181%	33.520%	51.907%	60.714%	34.017%	29.060%
Lima	20.690%	27.85%	40.789%	82.051%	100.000%	56.852%	19.703%	50.000%	100.000%	4.274%
Amsterdam	31.897%	100.00%	38.158%	100.000%	79.518%	100.000%	100.000%	0.000%	83.993%	100.000%

Appendix table 3.4.2 Correlation matrix of Smart Living indicators

	Number of museums	**IESE International outreach ranking (out of 181 cities)**	**Life expectancy of residents at birth**	**Number of crimes per 100.000 inhabitants**	**Poverty ratio**	**Average working hours per year of worker**	**Domestic purchasing power (net annual income)**	**Values for average rent prices**	**Population density**	**Quality of living ranking (out of 231 cities)**
Number of museums	1.0000	0.317	-0.4951	0.0351	-0.6748	0.0619	-0.3913	-0.0966	-0.4404	-0.0677
IESE International outreach ranking (out of 181 cities)	0.317	1.000	0.029	0.623	-0.026	0.588	0.636	**-0.914****	-0.058	**0.880****
Life expectancy of residents at birth	-0.4951	0.029	1.0000	0.4821	0.1524	-0.0476	0.3769	-0.3143	-0.2974	0.3190
Number of crimes per 100,000 inhabitants	0.0351	0.623	0.4821	1.0000	0.2736	0.0716	0.2686	**-0.7845****	-0.2665	0.6088
Poverty ratio	-0.6748	-0.026	0.1524	0.2736	1.0000	0.2487	0.2986	-0.0549	0.3036	0.2061
Average working hours per year of worker	0.0619	0.588	-0.0476	0.0716	0.2487	1.0000	0.6710	-0.4104	0.0316	0.5941
Domestic purchasing power (net annual income)	-0.3913	0.636	0.3769	0.2686	0.2986	0.6710	1.0000	-0.6096	0.1094	**0.8786****
Values for average rent prices	-0.0966	**-0.914****	-0.3143	**-0.7845****	-0.0549	-0.4104	-0.6096	1.0000	-0.0485	**-0.8317****
Population density	-0.4404	-0.058	-0.2974	-0.2665	0.3036	0.0316	0.1094	-0.0485	1.0000	-0.1236
Quality of living ranking (out of 231 cities)	-0.0677	**0.880****	0.3190	0.6088	0.2061	0.5941	**0.8786****	**-0.8317****	-0.1236	1.0000

** Significantly correlated at p=0.05

Appendix table 3.4.3 Principal components (PCA – FactoMineR) – Smart Living

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Eigenvalues	4.386	2.202	1.563	0.911	0.682	0.256
% of var.	43.859 %	22.023 %	15.633 %	9.115 %	6.816 %	2.556 %
Cumulative % of var.	43.859 %	65.881 %	81.514 %	90.629 %	97.444 %	100.000 %

Appendix table 3.4.4 Factor loadings of Smart Living's indicators.
Extraction method: principal components, varimax rotation

	RC1	RC2	RC3
Number of museums	0.12	-0.97	-0.15
IESE International outreach ranking (out of 181 cities)	0.95	-0.23	0.11
Life expectancy of residents at birth	0.06	0.37	0.84
Number of crimes per 100,000 inhabitants	0.51	-0.03	0.72
Poverty ratio	0.15	0.79	0.04
Average working hours per year of worker	0.76	0.11	-0.30
Domestic purchasing power (net annual income)	0.80	0.43	0.09
Values for average rent prices (monthly gross rents) for local households (normal local rent)	-0.86	0.05	-0.34
Population density	0.06	0.54	-0.58
Quality of living ranking (out of 231 cities)	0.92	0.11	0.29

Appendix table 3.4.5 Weights for the Smart Living's indicators.
Extraction method: Principal components, varimax rotation

Number of museums	0.138
IESE International outreach ranking (out of 181 cities)	0.132
Life expectancy of residents at birth	0.103
Number of crimes per 100,000 inhabitants	0.076
Poverty ratio	0.091
Average working hours per year of worker	0.085
Domestic purchasing power (net annual income)	0.093
Values for average rent prices (monthly gross rents) for local households (normal local rent)	0.108
Population density	0.049
Quality of living ranking (out of 231 cities)	0.124
Total	**1.000**

Appendix table 3.5.1 Normalised values of Smart Environment indicators

	Smart Environmental Quality				Smart Water	Smart Waste	
	Particulate matter (PM10) concentration	Fine particulate matter (PM2.5) concentration	Greenhouse gas emissions	Green space per person	Water consumption	Share of waste collected and adequately disposed	Waste generated per person
Mexico city	73.016%	82.353%	72.606%	25.071%	88.520%	100.000%	37.022%
Rio de Janeiro	61.905%	94.118%	100.000%	53.181%	66.300%	93.607%	25.577%
Buenos Aires	98.413%	100.000%	63.029%	3.894%	0.000%	100.000%	0.000%
Bogota	57.143%	70.588%	72.606%	100.000%	100.000%	98.630%	100.000%
Santiago	38.095%	55.882%	72.160%	22.887%	76.807%	94.977%	13.595%
Lima	0.000%	0.000%	90.423%	0.000%	93.296%	0.000%	92.286%
Amsterdam	100.000%	88.235%	0.000%	14.834%	96.089%	100.000%	37.632%

Appendix table 3.5.2 Correlation matrix of Smart Environment indicators

	Particulate matter (PM10) concentration	**Fine particulate matter (PM2.5) concentration**	**Greenhouse gas emissions**	**Green space per person**	**Water consumption**	**Share of waste collected and adequately disposed**	**Waste generated per person**
Particulate matter (PM10) concentration	1.0000	0.9166**	-0.6266	0.0156	-0.4217	0.8026**	-0.5568
Fine particulate matter (PM2.5) concentration	0.9166**	1.0000	-0.3293	0.2335	-0.4458	0.9082**	-0.6209
Greenhouse gas emissions	-0.6266	-0.3293	1.0000	0.2234	-0.1109	-0.3567	0.1683
Green space per person	0.0156	0.2335	0.2234	1.0000	0.3512	0.3799	0.4428
Water consumption	-0.4217	-0.4458	-0.1109	0.3512	1.0000	-0.2426	0.6833
Share of waste collected and adequately disposed	0.8026**	0.9082**	-0.3567	-0.3799	-0.2426	1.0000	-0.5489
Waste generated per person	-0.5568	-0.6209	0.1683	0.4428	0.6833	-0.5489	1.0000

** Significantly correlated at p=0.05

Appendix table 3.5.3 PC (PCA – FactoMineR) – Smart Environment

	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalues	3.684	1.689	1.159	0.336	0.107	0.023
% of var	52.624 %	24.129 %	16.563 %	4.798 %	1.522 %	0.364 %

Appendix table 3.5.4 Factor loadings of Smart Environment's indicators.
Extraction method: principal components, varimax rotation

	RC1	RC2	RC3
Particulate matter (PM10) concentration	0.81	-0.29	-0.45
Fine particulate matter (PM2.5) concentration	0.94	-0.27	-0.11
Greenhouse gas emissions	-0.27	-0.05	0.95
Green space per person	0.52	0.71	0.45
Water consumption	-0.26	0.87	-0.20
Share of waste collected and adequately disposed	0.96	-0.08	-0.11
Waste generated per person	-0.42	0.83	0.12

Appendix table 3.5.5 Weights for the Smart Environment's indicators.
Extraction method: Principal components, varimax rotation

Particulate matter (PM10) concentration	0.123
Fine particulate matter (PM2.5) concentration	0.166
Greenhouse gas emissions	0.170
Green space per person	0.095
Water consumption	0.142
Share of waste collected and adequately disposed	0.173
Waste generated per person	0.130
Total	**1.000**

Appendix table 3.6.1 Normalised values of Smart Infrastructure indicators

	Smart Mobility					Smart Utilities			Smart ICT
	Length of mass transport network	Number of deaths in traffic accidents (national)	Stock of cars and motorcycles	Metro network length	IESE Mobility performance ranking (out of 181 cities)	% Households without sanitation	% Households without drinking water	% Households without electricity supply service	IESE Technology performance ranking (out of 181 cities)
Mexico city	44.030%	59.138%	50.000%	100.000%	90.299%	75.000%	100.000%	92.857%	45.528%
Rio de Janeiro	100.000%	0.000%	76.923%	27.598%	82.836%	0.000%	80.000%	97.143%	21.951%
Buenos Aires	70.149%	89.007%	0.000%	26.803%	78.358%	87.500%	100.000%	70.000%	38.211%
Bogota	68.284%	86.582%	98.077%	0.000%	0.000%	75.000%	100.000%	85.714%	20.325%
Santiago	34.701%	97.614%	100.000%	50.920%	47.015%	100.000%	100.000%	85.714%	0.000%
Lima	36.567%	94.045%	100.000%	17.106%	26.866%	0.000%	0.000%	0.000%	4.065%
Amsterdam	0.000%	100.000%	48.077%	21.134%	100.000%	100.000%	100.000%	100.000%	100.000%

Appendix table 3.6.2 Correlation matrix of Smart Infrastructure indicators

	Length of mass transport network	**Number of deaths in traffic accidents (national)**	**Stock of cars and motorcycles**	**Metro network length**	**IESE Mobility performance ranking (out of 181 cities)**	**% Households without sanitation**	**% Households without drin king water**	**% Households without electricity supply service**	**IESE Technology performance ranking (out of 181 cities)**
Length of mass transport network	1.0000	-0.7261	-0.0262	-0.1393	-0.1576	-0.4819	0.0567	0.1020	-0.4919
Number of deaths in traffic accidents (national)	-0.7261	1.0000	-0.0189	-0.1894	-0.3209	0.5911	-0.0475	-0.3268	0.1283
Stock of cars and motorcycles	-0.0262	-0.0189	1.0000	-0.2085	-0.6820	-0.3713	-0.4101	-0.2574	-0.5765
Metro network length	-0.1393	-0.1894	-0.2085	1.0000	0.4958	0.2136	0.2631	0.2689	0.0545
IESE Mobility performance ranking (out of 181 cities)	-0.1576	-0.3209	-0.6820	0.4958	1.0000	0.1787	0.3557	0.4708	0.6708
% Households without sanitation	-0.4819	0.5911	-0.3713	0.2136	0.1787	1.0000	0.7636**	0.5303	0.4375
% Households without drinking water	0.0567	-0.0475	-0.4101	0.2631	0.3557	0.7636**	1.0000	0.9179**	0.4089
% Households without electricity supply service	0.1020	-0.3268	-0.2574	0.2689	0.4708	0.5303	0.9179**	1.0000	0.4667
IESE Technology performance ranking (out of 181 cities)	-0.4919	0.1283	-0.5765	0.0545	0.6708	0.4375	0.4089	0.4667	1.0000

** Significantly correlated at p=0.05

Appendix table 3.6.3 PC (PCA – FactoMineR) – Smart Infrastructure

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Eigenvalues	3.715	2.213	1.334	0.967	0.667	0.103
% of var.	41.281 %	24.593 %	14.821 %	10.743%	7.415 %	1.145 %
Cumulative % of var.	41.281 %	65.875 %	80.696 %	91.440 %	98.855 %	100.000 %

Appendix table 3.6.4 Factor loadings of Smart Infrastructure's indicators.
Extraction method: principal components, varimax rotation

	RC1	RC2	RC3
Length of mass transport network	-0.21	-0.89	0.09
Number of death in traffic accidents (national)	-0.24	0.95	0.00
Stock of cars and motorcycles	-0.75	-0.08	-0.20
Metro network length	0.50	-0.10	0.15
IESE Mobility performance ranking (out of 181 cities)	0.96	-0.08	0.13
% Households without sanitation	0.14	0.62	0.75
% Households without drinking water	0.25	0.00	0.97
% Households without electricity supply service	0.33	-0.20	0.88
IESE Technology performance ranking (out of 181 cities)	0.73	0.39	0.25

Appendix table 3.6.5 Weights for the Smart Infrastructure's indicators.
Extraction method: Principal components, varimax rotation

Length of mass transport network	0.127
Number of deaths in traffic accidents (national)	0.145
Stock of cars and motorcycles	0.090
Metro network length	0.040
IESE Mobility performance ranking (out of 181 cities)	0.148
% Households without sanitation	0.090
% Households without drinking water	0.151
% Households without electricity supply service	0.124
IESE Technology performance ranking (out of 181 cities)	0.086
Total	**1.000**

Appendix 4: Weighted results

Appendix table 4.1 Weighted score – Smart Governance

	Corruption Perception Index score (national (out of 176 countries)	**Weighted score**
Mexico city	0.000%	**0.000%**
Rio de Janeiro	38.261%	**38.261%**
Buenos Aires	24.348%	**24.348%**
Bogota	28.696%	**28.696%**
Santiago	86.087%	**86.087%**
Lima	19.130%	**19.130%**
Amsterdam	100.000%	**100.000%**

Appendix table 4.2 Weighted score – Smart Economy

	Smart Innovation		Smart productivity						
	Patent applications	Innovative cities ranking	Number of HQ on Forbes 2000	GDP per capita 2014 (PPP, $)	Unemployment rate	Global network integration	Ease of doing business - composite indicator	IESE Economy performance ranking	**Weighted score**
Mexico city	0.695%	10.116%	7.105%	5.771%	13.119%	9.854%	11.554%	13.907%	**72.121%**
Rio de Janeiro	2.181%	8.011%	2.583%	4.109%	0.000%	0.000%	0.000%	0.000%	**16.884%**
Buenos Aires	0.306%	11.215%	0.000%	7.204%	1.753%	7.390%	1.212%	4.992%	**34.073%**
Bogota	0.185%	3.708%	0.646%	5.199%	2.922%	7.390%	9.465%	10.341%	**39.856%**
Santiago	0.243%	6.088%	3.875%	7.310%	9.058%	7.390%	10.787%	13.669%	**58.421%**
Lima	0.000%	0.000%	0.000%	0.000%	9.934%	4.927%	9.494%	8.439%	**32.795%**
Amsterdam	11.979%	13.412%	8.396%	14.311%	6.720%	9.854%	14.300%	14.620%	**93.593%**

Appendix table 4.3 Weighted score – Smart Education

	Number of universities in Top 200 worldwide	Average years of schooling	Quality of education: adult illiteracy rate	Total public expenditure on education as a % of GDP	**Weighted score**
Mexico city	**25.088%**	**13.327%**	**16.561%**	**20.930%**	**75.906%**
Rio de Janeiro	**0.000%**	**4.882%**	**0.000%**	**28.429%**	**33.311%**
Buenos Aires	**25.088%**	**24.020%**	**22.463%**	**20.818%**	**92.389%**
Bogota	**0.000%**	**0.000%**	**15.838%**	**18.468%**	**34.306%**
Santiago	**25.088%**	**17.047%**	**22.463%**	**14.215%**	**78.812%**
Lima	**0.000%**	**12.398%**	**12.827%**	**0.000%**	**25.225%**
Amsterdam	**25.088%**	**19.371%**	**19.452%**	**25.183%**	**89.094%**

Appendix table 4.4 Weighted score – Smart Living

	Smart Culture	Smart Tourism	Smart Health	Smart Safety	Smart Poverty Management	Smart Jobs		Smart Housing	Smart Quality of Living		
	Number of museums	IESE International outreach ranking (out of 181 cities)	Life expectancy of residents at birth	Number of crimes per 100.000 inhabitants	Poverty ratio	Average working hours per year of worker	Domestic purchasing power (net annual income)	Values for average rent prices	Population density	Quality of living ranking (out of 231 cities)	**Weighted score**
Mexico city	**12.111%**	**5.013%**	**0.408%**	**4.436%**	**0.000%**	**0.000%**	**0.000%**	**5.802%**	**3.708%**	**0.106%**	**31.583%**
Rio de Janeiro	**9.261%**	**4.344%**	**0.000%**	**0.000%**	**2.064%**	**8.147%**	**4.029%**	**8.123%**	**4.002%**	**1.165%**	**41.135%**
Buenos Aires	**13.773%**	**6.516%**	**1.767%**	**6.187%**	**4.788%**	**5.714%**	**1.846%**	**6.575%**	**0.000%**	**3.812%**	**50.979%**
Bogota	**0.000%**	**0.000%**	**0.054%**	**1.479%**	**8.806%**	**2.602%**	**2.739%**	**10.830%**	**4.472%**	**0.000%**	**30.981%**
Santiago	**0.831%**	**2.506%**	**10.330%**	**5.020%**	**4.128%**	**2.834%**	**4.863%**	**6.575%**	**1.675%**	**3.600%**	**42.362%**
Lima	**2.850%**	**3.676%**	**4.214%**	**6.226%**	**9.136%**	**4.807%**	**1.846%**	**5.415%**	**4.924%**	**0.529%**	**43.622%**
Amsterdam	**4.393%**	**13.200%**	**3.942%**	**7.588%**	**7.265%**	**8.455%**	**9.368%**	**0.000%**	**4.136%**	**12.390%**	**70.736%**

Appendix table 4.5 Weighted score – Smart Environment

	Smart Environmental Quality				Smart Water	Smart Waste		
	Particulate matter (PM10) concentration	Fine particulate matter (PM2.5) concentration	Greenhouse gas emissions	Green space per person	Water consumption	Share of waste collected and adequately disposed	Waste generated per person	**Weighted score**
Mexico city	**8.981%**	**13.671%**	**12.343%**	**2.382%**	**12.570%**	**17.300%**	**4.813%**	**72.059%**
Rio de Janeiro	**7.614%**	**15.624%**	**17.000%**	**5.052%**	**9.415%**	**16.194%**	**3.325%**	**74.224%**
Buenos Aires	**12.105%**	**16.600%**	**10.715%**	**0.370%**	**0.000%**	**17.300%**	**0.000%**	**57.090%**
Bogota	**7.029%**	**11.718%**	**12.343%**	**9.500%**	**14.200%**	**17.063%**	**13.000%**	**84.852%**
Santiago	**4.686%**	**9.276%**	**12.267%**	**2.174%**	**10.907%**	**16.431%**	**1.767%**	**57.509%**
Lima	**0.000%**	**0.000%**	**15.372%**	**0.000%**	**13.248%**	**0.000%**	**11.997%**	**40.617%**
Amsterdam	**12.300%**	**14.647%**	**0.000%**	**1.409%**	**13.645%**	**17.300%**	**4.892%**	**64.193%**

Appendix table 4.6 Weighted score – Smart Infrastructure

	Smart Mobility					Smart Utilities			Smart ICT	
	Length of mass transport network	Number of deaths in traffic accidents (national)	Stock of cars and motorcycles	Metro network length	IESE Mobility performance ranking (out of 181 cities)	% Households without sanitation	% Households without drinking water	% Households without electricity supply service	IESE Technology performance ranking (out of 181 cities)	**Weighted score**
Mexico city	**5.587%**	**8.554%**	**4.508%**	**4.000%**	**13.337%**	**6.750%**	**15.080%**	**11.514%**	**3.888%**	**73.218%**
Rio de Janeiro	**12.690%**	**0.000%**	**6.935%**	**1.104%**	**12.235%**	**0.000%**	**12.064%**	**12.046%**	**1.875%**	**58.948%**
Buenos Aires	**8.902%**	**12.874%**	**0.000%**	**1.072%**	**11.574%**	**7.875%**	**15.080%**	**8.680%**	**3.263%**	**69.320%**
Bogota	**8.665%**	**12.524%**	**8.842%**	**0.000%**	**0.000%**	**6.750%**	**15.080%**	**10.629%**	**1.736%**	**64.225%**
Santiago	**4.404%**	**14.119%**	**9.015%**	**2.037%**	**6.944%**	**9.000%**	**15.080%**	**10.629%**	**0.000%**	**71.227%**
Lima	**4.640%**	**13.603%**	**9.015%**	**0.684%**	**3.968%**	**0.000%**	**0.000%**	**0.000%**	**0.347%**	**32.258%**
Amsterdam	**0.000%**	**14.465%**	**4.334%**	**0.845%**	**14.770%**	**9.000%**	**15.080%**	**12.400%**	**8.540%**	**79.434%**