U.PORTO

FEP FACULDADE DE ECONOMIA
UNIVERSIDADE DO PORTO

WHY ARE SOME CITIES MORE "SMART SUSTAINABLE" THAN OTHERS? – THE PORTUGUESE PANORAMA

Marta Sousa Brenha

Dissertation

Master in Economics

Supervised by

Maria Isabel Mota

2022

Acknowledgments

With my journey as a student finishing here (or at least for now, I believe), I would like to take this opportunity to thank everyone who has, in one way or another, helped me conclude this chapter of my life.

To my family – thank you for always supporting me in my decisions and letting me create my own path. I would also like to thank my friends, my colleagues at Porto City Hall and ShARE-UP for sparking in me the interest in the topic of smart sustainable cities – it sure made writing this dissertation a very enjoyable process.

Finally, I would like to thank the Faculty of Economics and Management of University of Porto (FEP), but mostly Professor Isabel Mota for doing such a great job as my supervisor and being so supportive and available throughout these past months. I feel very privileged to have had such a positive experience.

Abstract

Intergovernmental organisations such as the United Nations, as well as national governments, are increasingly concerned about making cities more sustainable. "Smart" technology such as information and communication technology, along with human capital, plays an important role in achieving such sustainability goals in urban areas. The concept of "smart sustainable cities" has emerged as a response and it has been gaining particular relevance not only in the literature but also in policymaking, but it still not very clear what factors determine a city's "smart sustainable" level. Our work aims to address this question, taking the specific case of 278 Portuguese municipalities as our object of study. Accordingly, we offer a composite index for measuring smart sustainable cities using exploratory factor analysis. Our index shows that the Centre and South regions in Portugal display higher levels in general, and countryside municipalities appear to perform better than coastal ones. Afterwards, the index is used as a dependent variable in an econometric model that is designed to study the factors that make a municipality score a higher level of "smart sustainability". Our findings suggest that a municipality's size or its classification as a city have no impact in its smart sustainable city score, although population density appears to be associated with more "smart sustainable" municipalities. There is also evidence that local governments that are not affiliated with national political parties perform better when it comes to this type of urban development. Furthermore, characteristics such as the immigrant share and the relative importance of the manufacturing sector are positively correlated to a city's level of "smart sustainability", whereas the ageing of population and average household size are negatively correlated.

JEL-codes: O18, O43, O44, Q56

Key-words: Smart sustainable cities, smart cities, urban development, Portugal

Resumo

Organizações intergovernamentais como a Organização das Nações Unidas, assim como os governos nacionais, estão cada vez mais preocupadas em tornar as cidades mais sustentáveis. A tecnologia "inteligente" como a tecnologia de informação e comunicação, junto do capital humano, tem um papel importante no que toca a atingir esses mesmos objetivos sustentáveis nas áreas urbanas. O conceito de "cidades inteligentes sustentáveis" emergiu como resposta e tem ganho particular relevância não só na literatura como nas políticas, mas ainda não é muito claro que fatores determinam o nível "inteligente sustentável" de uma cidade. Este trabalho pretende responder a esta questão, considerando o caso específico de 278 municípios portugueses como o seu objeto de estudo. Nesse sentido, é oferecido um índice compósito para medir cidades inteligentes sustentáveis usando análise fatorial exploratória. Este índice mostra que as regiões centro e sul de Portugal exibem níveis mais elevados em geral, e municípios do interior parecem ter uma melhor performance do que os do litoral. Posteriormente, o índice é utilizado como variável dependente num modelo econométrico desenhado para estudar os fatores que fazem com que um município obtenha um nível mais elevado de "sustentabilidade inteligente". Os resultados sugerem que o tamanho de um município ou a sua classificação como cidade não têm impacto no seu nível de cidade inteligente sustentável, embora a densidade populacional esteja associada a municípios mais "inteligentes sustentáveis". Existe também evidência de que os governos locais que não estão afiliados a um partido nacional têm uma melhor *performance* no que toca a este tipo de desenvolvimento urbano. Além disso, características como a percentagem de imigrantes ou o peso da indústria transformadora estão positivamente correlacionadas com o nível de "sustentabilidade inteligente" de uma cidade, enquanto que o envelhecimento populacional e a dimensão média dos agregados familiares estão negativamente correlacionados.

Códigos-JEL: O18, O43, O44, Q56

Palavras-chave: Cidades inteligentes e sustentáveis, cidades inteligentes, desenvolvimento urbano, Portugal

Contents

List of tables

List of figures

Chapter 1. Introduction

In 2015, the adoption of the 2030 Agenda for Sustainable Development by the members of the United Nations (UN) represented an important milestone in the international commitment and cooperation towards a more sustainable future, encompassing goals in terms of poverty reduction, health improvement, economic growth and environmental change (United Nations, 2015). A particular goal of this agenda is the 11^{th} - Sustainable Cities and Communities -, which aims to make cities greener, safer, and more inclusive to current and future generations. This concern arises from the fact that it is estimated that 68% of the global population will live in urban areas by 2050 and cities account for around 75% of global carbon emissions and energy consumption, even if they only represent 3% of the land (United Nations, 2020).

As a response to these challenges, cities worldwide have been adopting several measures in order to become more sustainable, some specifically through the adoption and development of information and communications technology (ICT), as Albino, Berardi, and Dangelico (2015) point out. The underlying concept here is the one of "smart cities", which the European Parliament prescribes as "a key strategy to tackle poverty and inequality, unemployment and energy management" in the context of urban areas (Manville et al., 2014). From the adoption of "smart city" technology in order to achieve urban sustainable development, we can, then, reach the goal of "smart sustainable city", which also considers the role of people and policy (Yigitcanlar et al., 2019).

The main goals of this study are, first, to offer a concept of "smart sustainable city"; second, to develop a framework to evaluate the smartness and sustainability of cities that can be applied to the case of Portuguese cities; finally, we aim to analyse which factors play a role in determining the differences in "smart sustainable" urban development across Portugal. We therefore aim to answer the following research question: which factors explain the current panorama of smart sustainable cities in Portugal?

This analysis seeks to address an existing gap in the literature regarding smart sustainable cities, which is the fact that, although there are many studies on what a smart/sustainable city is, as well as indices that assess how municipalities around the world are doing in respect to that, the topic of a city being simultaneously smart and sustainable is roughly explored. Moreover, there are very few contributions on what actually determines a city being less or more smart/sustainable than another. Aside from being scarce, the existing literature on these determinants is either not comprehensive enough by focusing more on explanatory variables related to governance characteristics (Nevado Gil, Carvalho, & Paiva, 2020), or it studies a geographic dimension that is too broad, which in turn makes the analysis not detailed enough and rather superficial (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014). This type of information is crucial to local governments, who determine policy at the municipality level, but also to higher-level institutions such as the European Commission, which is responsible for creating agendas and mobilising funds aimed at promoting sustainable economic growth (European Commission, n.d.-b). Our work intends, then, to identify the main limitations that cities are facing when it comes to their investments in smart sustainable city projects, so they can be overcome through policy.

Furthermore, there are not many studies regarding the performance of smaller cities, as opposed to larger ones, even though smart sustainable initiatives can be implemented regardless of the size of the municipality (Neirotti et al., 2014) – smaller towns or villages are usually absent from those studies (Berrone & Ricart, 2020; Giffinger & Gudrun, 2010) or, in the case they are present, the sample size is small (INTELI & CEIIA, 2016). In that sense, we decided to base this work off Portuguese municipalities, a sample composed by mostly small cities and villages, as a way to fulfil this second gap in the literature. In particular, we start by constructing a composite index aimed at measuring the smart sustainable city level of mainland Portuguese municipalities, through exploratory factor analysis, which is a more accurate weighting technique that takes into account possible structural correlations between variables (Hair, Black, Babin, & Anderson, 2014). Then, taking the result obtained by each municipality for that index, an econometric model is built with the purpose of assessing which factors determine a municipality's smart sustainable city level being higher or lower. Our model includes explanatory variables among 4 dimensions - demographic, institutional (economic and governance), economic sectors, spatial -, inspired by the literature (da Cruz & Marques, 2014; Neirotti et al., 2014). By providing that picture of Portuguese municipalities, as well as discussing the reasons as to why levels of smart sustainability differ across them, this study aims, thus, at suggesting the adequate local policy in order to boost smart sustainable urban development in Portugal.

Departing from this introduction, this dissertation is structured as follows. Chapter 2 explores the concepts of "sustainable city", "smart city", and "smart sustainable city", as well as the literature on the performance assessment and the determining factors of this type of urban development. Chapter 3 studies the Portuguese panorama of smart cities, by briefly analysing the literature and constructing a composite index aimed at assessing smart sustainable cities. In Chapter 4, the econometric study of the determinants of smart sustainable cities is done, with the creation of the model and further presentation and discussion of its results. This dissertation is finalized in Chapter 5, in which the main conclusions are drawn and the limitations of this work and future research paths are discussed.

Chapter 2. Smart sustainable cities – what are they and where do they come from?

In order to accurately assess what a "smart sustainable city" is, it is important to ground on some key concepts. We start with the concept of "city" and then we go through the historical context of "smart sustainable city" – the concept of "sustainable city" (section 2.1.) was followed by the concept of "smart city" (section 2.2.) and, nowadays, the concept of "smart sustainable city" (section 2.3.) has been gaining popularity.

After comprehending the differences between these concepts, it also important to understand how a smart sustainable city is usually assessed (section 2.4.), as doing that is one of the objectives of this work. Similarly, a literature review of the determinants of smart sustainable cities must also be conducted (section 2.5.)

2.1. An initial concept - sustainable city

Before diving into the concepts of "smart" or "sustainable", we must first understand what is meant by "city". Using the definition proposed by the OECD and the European Commission, a city is a municipality (or "local administrative unit") with at least 50% of its population living inside an urban centre, which is characterized as a cluster of contiguous high-density grid cells with at least 50000 inhabitants (Dijkstra & Poelman, 2012). Taking that into consideration, it is then important to understand the historical context of smart sustainable urban development, which started with the early concept of "sustainable city".

The absolute core concept around sustainable cities is sustainable development. According to Brundtland in his report for the United Nations (World Commission on Environment and Development, 1987):

> *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* (p. 41).

If that definition is applied to urban areas, it means that a city is sustainable when its future is taken into consideration and not compromised by current actions. Cities represent the interaction of society, the economy, and the environment, so sustainability is the existence of harmony between those three dimensions (Camagni, Capello, & Nijkamp, 1998; Nijkamp & Perrels, 2014).

In the context of climate change and environmental degradation, the main challenge cities face is the minimization of the negative externalities that arise from daily activities, without compromising economic growth (Hiremath, Balachandra, Kumar, Bansode, & Murali, 2013). Accessibility and inclusion are also mandatory for a city to be considered sustainable (United Nations, 2015), since intra-generational fairness is also important (Camagni et al., 1998). What this means is that a city can only be sustainable if it is so for everyone.

As mentioned in the Reference Framework for Sustainable Cities (2016) as well by other authors (Camagni et al., 1998; Hatuka, Rosen-Zvi, Birnhack, Toch, & Zur, 2018; Nijkamp & Perrels, 2014), we can, in practical terms, assess urban sustainability of a city in terms of the accessibility, efficiency and inclusivity of its transportation systems, water use and waste management, power grid, buildings and spaces, labour and housing market, and even healthcare.

2.2. A modern approach – smart city

Smart city is a term that is, increasingly, in the mouth of municipalities all around the world. But what does it mean, exactly? It is difficult to dissociate the term "smart" from other words such as "digital" or "intelligent" (Hollands, 2008), so the definition of a smart city is often related to the role of ICT in providing a higher quality of life to citizens through innovation (González & Rossi, 2011; Piro, Cianci, Grieco, Boggia, & Camarda, 2014). This very technology-centered point of view is often criticized in the literature since technology is a necessary but not sufficient condition for the real improvement of the well-being of the society, economy and environment (Hollands, 2008; Martin, Evans, & Karvonen, 2018; Yigitcanlar et al., 2019). Nevertheless, the most common approach to smart cities goes beyond the diffusion of ICT and establishes urban sustainable development as the main goal, considering the needs of the community and the natural environment (Albino et al., 2015; Caragliu, Del Bo, & Nijkamp, 2009; Manville et al., 2014; Zygiaris, 2013). In fact, a city cannot be characterized as "smart" if it is not "sustainable" as well (Ahvenniemi, Huovila, Pinto-Seppä, & Airaksinen, 2017; Yigitcanlar et al., 2019).

Combining the previously defined concept of urban sustainability, a city can then be considered smart if its investments in ICT, as well as in human and social capital and transportation infrastructure, act as an enabler of the simultaneous improvement of the three dimensions of the city – the economy, the society and the environment (Caragliu et al., 2009). Manville et al. (2014) propose a definition of smart city grounded in six axes: smart economy, smart mobility, smart environment, smart people, smart living and smart governance.

2.3. Bridging the two concepts – smart sustainable city

If smart cities are already sustainable, then what is the purpose of adopting a concept of "smart sustainable cities"? First, including the word "sustainable" clarifies that we are not taking the techno-centric approach of smart cities; instead, environmental, economic, and social sustainability is also being considered. Furthermore, the adoption of this concept also improves the traditional notion of urban sustainability by taking into account the fact that cities are increasingly digitalized (Huovila, Bosch, & Airaksinen, 2019). In that sense, the International Telecommunications Union (2016) proposes the following definition:

> *"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects." (p. 2).*

This concept distinguishes itself from the sole idea of "smart city" by emphasizing that, although ICT play an important part in urban sustainable development, it is important to consider the role of citizens and policymakers as well (Yigitcanlar et al., 2019). Furthermore, even if some of the literature in smart cities does not solely focus on ICT, the adoption of the concept "smart sustainable city" clarifies that other drivers to urban sustainable development are being taken into account. Since the concept of smart sustainable city provides a holistic and comprehensive approach to urban development, it is gaining importance in the literature (Höjer & Wangel, 2015; Martin et al., 2018; Yigitcanlar et al., 2019).

2.4. Measuring smart sustainable cities

In order to accurately understand the concept of smart sustainable cities, it is important to understand which characteristics are to be assessed. With data becoming increasingly accessible and rapidly available, policymakers require a few clear but comprehensive key performance indicators (KPIs) in order to accurately understand their level of smart and sustainable development (Huovila et al., 2019). That being said, a quantitative approach is useful, as it is more objective, allowing for both a clearer identification of which areas require more investments as well as a comparison between peers (other cities).

Currently, there are many assessment frameworks that have been developed for both smart and sustainable cities, however the concept of smart sustainable cities is still lacking in terms of guidance in how to measure such development in cities. There are several indices for smart cities (see Table 1 for a more detailed description), but a commonly referenced one is the European Smart Cities Ranking (Giffinger & Gudrun, 2010), which considers 74 indicators grouped into the six smart city dimensions proposed by Manville et al. (2014) – smart economy, smart people, smart governance, smart mobility, smart environment and smart living. On the other hand, sustainable city assessment is usually measured following the indicators for the targets of the 17 Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda for Sustainable Development (United Nations, 2015), which are the international standard for monitoring urban sustainable development. In that scope, a particularly interesting index is the Sustainable Development Index at the Municipal Level (Abreu, António, & Cerol, 2020), which attributes scores to all Portuguese municipalities based off 130 indicators (115 unique ones) associated to those targets. More sustainable city assessment frameworks can be found on Table 2.

Table 1: List of smart city indices and assessment frameworks

Name	Dimensions	Number of indicators	Source
European Smart Cities	Smart economy, smart people, smart governance, smart mobility, smart environment, smart living	31	Giffinger and Gudrun (2010)
Smart City Index Master Indicators	Environment, mobility, government, economy, people, living	46	Cohen (2014)
CITYKeys Indicators for Smart Cities	People, planet, prosperity and governance	73	Bosch et al. (2017)
Cities in Motion Index	Human capital, social cohesion, economy, governance, the environment, mobility and transportation, urban planning, international projection, technology	101	Berrone and Ricart (2020)
Global Power City Index	Economy, R&D, cultural interaction, liveability, environment, accessibility	70	MMF (2021)
Smart City Index	Health and safety, mobility, activities, opportunities (work and school), governance	39	IMD (2021)
Smart City Index Portugal	Governance, innovation, sustainability, quality of life, connectivity	190	INTELI and CEIIA (2016)

Source: Own elaboration

Table 2: List of sustainable city assessment frameworks

Name	Dimensions	Number of indicators	Source
Sustainable Development Index at the Municipal Level	UN's 17 SDGs: No poverty; zero hunger: good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation and infrastructure; reduced inequalities; sustainable cities and communities; climate action; life below water; life on land; peace, justice and strong institutions; partnerships for the goals	129 (115 unique indicators)	Abreu et al. (2020)
Reference Framework for Sustainable Cities	Spatial, governance, social, economic, environmental	30	Reference Framework for Sustainable Cities (2016)
Urban Sustainability Index	Social welfare, environment (cleanliness + built environment), economy, resources	23	Li, Li, Woetzel, Zhang, and Zhang (2014)
European Green Capital Award	Air quality, noise, water, sustainable land use and soil, waste and circular economy, nature and biodiversity, green growth and eco-innovation, climate change: mitigation, climate change: adaptation, sustainable urban mobility, energy performance, environmental performance	12	(European Commission, n.d.-a)
European Green City Index	CO2, energy, buildings, transport, water, waste and land use, air quality, environmental governance	30	Shields and Langer (2009)
ISO 37120:2018 Sustainable cities and communities—Indicators for city services and quality of life	Economy, education, energy, environment and climate change, finance, governance, health, housing, population and social conditions, recreation, safety, solid waste, sport and culture, telecommunication, transportation, urban/local agriculture and food security, urban planning, wastewater, water	131	International Organization for Standardization (2018)

Source: Own elaboration

As Ahvenniemi et al. (2017) studied, smart city assessment frameworks tend to not focus as much on the environment as sustainable city frameworks do; in contrast, sustainable city assessment frameworks usually lack emphasis on the economy when compared to smart city measures. This highlights the need for "smart sustainable city" indexes that combine features from both smart and sustainable city frameworks. There are international indicator standards (ISO 37120, ISO 37122, ETSI TS 103 463, ITU 4901, ITU 4902, ITU 4903 and the UN SDG 11 targets and indicators) that already measure smart sustainability, but Huovila et al. (2019) observed that some indicators are too focused on either sustainability or smartness as standalone concepts, and do not provide the necessary balance between both. Furthermore, these authors also pointed out the distinction between "hard" and "soft" smartness indicators – hard smartness relates to the dimensions of ICT, transport, water, waste and energy, whereas soft smartness is associated to dimensions such as social, cultural and human capital, inclusion, and the economy -, which the aforementioned standards address in varied proportions.

A possible solution to this issue is the creation of an index for smart sustainable cities, which can be anchored in the framework proposed by Ahvenniemi et al. (2017) and already adopted by Huovila et al. (2019), which includes 10 dimensions: natural environment; built environment; water and waste; transport; energy; economy; education, culture, innovation and science; health, well-being and safety; governance and citizen engagement; ICT. This framework comes as an adaptation of the one initially proposed by Neirotti et al. (2014), whose work consisted in a taxonomy of smart city application domains and, although relevant, appears too focused on the role of ICT in urban development. Pira (2021) also developed a suggestion of a smart sustainable city assessment framework based on a taxonomy of existing indicators for smart cities and sustainable development, considering socio-cultural, economic, environmental, and governmental dimensions.

The United For Smart Sustainable Cities Initiative (U4SSC, 2017), although not an index in itself, provides several KPIs that are useful and relevant to measure a city's level of smart sustainability. This framework includes 91 indicators among 7 dimensions - energy; education, health and culture; environment; infrastructure; ICT; productivity; safety, housing and social inclusion – and it is closely aligned with the aforementioned literature on smart sustainable cities. Therefore, this is a starting point to consider when developing a composite index to measure the level of smart and sustainable urban development in Portuguese municipalities.

2.5. What drives smart sustainable urban development?

Although the literature on sustainable, smart, and even smart sustainable cities is vast, a relevant aspect of these concepts that is still lacking attention is understanding what the driving factors of smart sustainable urban development are. This topic is important because, if some cities are lagging behind, policymakers should be aware of the causes in order to accurately address them and increase the level of smart sustainability of cities. Nevertheless, there are already some studies on this topic that can already provide some insights as to which could be the drivers of smart sustainable city development.

The existence of geographic clusters in smart sustainable city levels appears to be a reality in Europe, for example, as Western cities tend to show higher levels than Eastern ones (Nevado Gil et al., 2020). This can be explained by the fact that Western European countries and cities tend to be richer, which means they have more resources to be allocated to smart and sustainable initiatives and investments (Akande, Cabral, Gomes, & Casteleyn, 2019; Neirotti et al., 2014). In that sense, a municipality's budget for smart and sustainable projects is a key aspect for the development of those (Bosch et al., 2017).

Some characteristics (Akande et al., 2019; Bosch et al., 2017; Neirotti et al., 2014; Nevado Gil et al., 2020) of policymakers themselves can also explain differences in the levels of smart sustainability across cities - Bosch et al. (2017) and Neirotti et al. (2014) present the type of leadership and political agenda strategies as driving forces for smart sustainable city development; on the other hand, Nevado Gil et al. (2020) concluded that female governors are associated to higher levels of urban smart sustainability. Other possible driving forces of smart sustainable urban development are city size, in particular demographic density, due to economies of scale, and the availability of green spaces (Neirotti et al., 2014).

Chapter 3. The Portuguese panorama of smart sustainable cities

After defining "smart sustainable city", the second objective of this work is to develop an assessment framework that measures the level of smart sustainable urban development in Portuguese cities. In that sense, we start by offering an overview of what has been already observed in terms of smart sustainable cities in Portugal (section 4.1.); then, we go through the process of constructing the smart sustainable city index in section 4.2.

3.1. What has been done in Portugal so far?

Although Portuguese cities are usually not an object of study in this field, interest in smart and sustainable urban development initiatives in Portugal has been increasing in the past years, mostly since 2012 with the emergence of European funding that could be used in the development and implementation of projects within this scope (Correia, Teixeira, & Marques, 2021). This is particularly highlighted by the Sustainable Cities 2020 strategy (Ministry of Environment, Spatial Planning and Energy, 2015) which provided guidelines for sustainable (and smart) urban development in Portuguese cities from 2014 to 2020.

In what regards smart sustainable development of individual Portuguese cities, there is a lack of studies, although there is some (nevertheless disperse) work already done on this topic. An interesting contribution is the one made by Rodrigues and Franco (2020), who have developed a composite index to measure urban sustainability for all 308 Portuguese municipalities. Despite the similarities to the work proposed by this dissertation, the authors' approach is quite different, as it is focused on understanding the dimensions and sub-dimensions of a sustainable city, as well as the weightings associated with each. Furthermore, a striking difference is the absence of "smartness" in that composite index, as it is solely aimed at measuring urban sustainability.

A more similar approach to ours can be found in the Smart City Index (Table 1), developed by INTELI and CEIIA (2016), which analysed the level of smart sustainable city development in 36 Portuguese municipalities that were a part of RENER (Portuguese Smart Cities Network). This index included 5 dimensions – governance, innovation, sustainability, quality of life, and connectivity – and, for the period between 2012 and 2016, it appointed Porto, Águeda, Cascais, Bragança and Guimarães as the leading cities in smart sustainable urban development.

Although this work intends to go beyond the assessment of the level of smart sustainable city development in Portugal – namely, by finding out its determinants -, it still aims to fulfil the current gap by providing a recent picture of Portuguese cities. Moreover, we intend to enrich the literature by making use of a larger, more diverse sample of cities, applying a quantitative approach as well. Looking at the particular example of the Smart City Index (INTELI & CEIIA, 2016), it would be interesting to see if other cities have caught up ever since or if the leader board remains unchanged, also taking into consideration that many cities are not covered by that index. The same rationale can be applied to dimensions – we aim to cover more dimensions too, in order to provide a more complete overview of smart sustainable city development in Portugal.

3.2. Constructing a composite index: methodological issues

Information must be presented to policymakers in a simplified manner, namely through the use of indicators (Hiremath et al., 2013). Particularly, composite indices are useful as they allow for a more comprehensive analysis being, at the same time, easier to interpret (Stanickova & Melecký, 2018).

This work makes use of data for the 278 municipalities in mainland Portugal (thus, excluding municipalities in Azores and Madeira Islands), which correspond to the European Union's Local Administrative Unit (LAU) level 1. Data is mainly from *Instituto Nacional de Estatística* (INE), but *Instituto do Emprego e Formação Profissiona*l (IEFP), Transparency International Portugal, MOBI.E and the websites of the metro service providers (*Metro do Porto*, *Metropolitano de Lisboa* and *Metro Transportes do Sul*) have also been used as information sources.

We offer a composite index that is built upon the existing smart/sustainable city indices (Table 1 and Table 2), as well as the aforementioned smart sustainable city assessment frameworks developed by Ahvenniemi et al. (2017) and U4SSC (2017), and is comprised of 7 dimensions - living conditions; economy; transport and mobility; education and culture; environment; ICT; governance – and 21 variables (which are measured by a total of 26 indicators), as it can be found in Table 3.

Table 3: Variables and dimensions in the smart sustainable city index: descriptive statistics

Dimension	Variable	Indicator	Abbre-viation	Year	Mean	Min.	Max.	Source
Living conditions	Inequality	Gini coefficient of gross reported income less personal income paid tax per tax household, %	LC1	2020	38.08	32.9	48.1	INE (2021)
	Purchasing power	Local purchasing power per capita index	LC2	2020	81.33	55.94	205.62	INE (2021)
	Quality of water	Safe water, %	LC3	2020	99.08	91.17	100	INE (2021)
	Healthcare	Number of physicians (transformation: divided by the total population)	LC4	2020	0.002	0.0004	0.034	INE (2021)
Economy	Competitiveness	Share of exports in total external trade, % (transformation: divided the number of exports by the sum of exports and imports)	ECO1	2021	52.77	0	99.98	INE (2022)
	Entrepreneurial ecosystem	Number of business births	ECO2	2020	528	13	145054	INE (2021)
	Unemployment	Registered unemployment (transformation: divided by the population between 15 and 64 years old)	ECO3	2021	0.057	0.024	0.146	IEFP (2021; 2022)
	R&D	Average expenditure on R&D, thousands of €[1] (transformation: divided by the total population)	ECO4	2019	0.047	0.002	0.34	INE (2021)
Transport and mobility	Low-carbon emission transport	Consumption of motor fuel by inhabitant, toe/inhabitant	TM1	2020	0.50	0.006	15.527	INE (2022)
		Number of electric vehicle charging stations (transformation: divided by the total population)	TM2	2022	0.0004	0	0.002	MOBI.E (2022)
	Public transport network	Number of metro stations (transformation: divided by the area)	TM3	2022	0.007	0	0.579	Metro Transportes do Sul (2022), Metro do Porto (2022), Metropolitano de Lisboa (2022)
		Proportion of employed and student population using collective mode of transport in commuting, %	TM5	2011	15.93	2.9	37.6	INE (2017)

[1] This variable was collected at the NUTS III level due to lack of available information at the municipality level.

	Walkability	Proportion of employed or student population using pedestrian mode in commuting, %	TM6	2011	19.87	7	52.6	INE (2017)
Education and culture	Student ICT Access	Average number of students enrolled in non-tertiary education by computer	EDU1	2019/2020	3.748	0.9	12.5	INE (2021)
	School enrolment	Gross enrolment rate in primary and lower secondary education, %	EDU2	2019/2020	108.99	63.7	181.2	INE (2021)
	Tertiary education	Population with tertiary education (transformation: divided by population over 15 years old)	EDU3	2021	0.140	0.051	0.423	INE (2022)
	Culture	Expenditure in cultural activities, € (transformation: divided by the total population)	EDU4	2020	63.68	4.06	405.87	INE (2021)
		Expenditure in cultural heritage, € (transformation: divided by the total population)	EDU5	2020	16.7	0	193.63	INE (2021)
Environment	Waste management	Urban waste management index, ranging from -100 to 100	ENV1	2020	-38.4	-95.3	78.2	INE (2022)
	Environmental protection	Number of firemen (transformation: divided by the area)	ENV2	2020	0.65	0	10.52	INE (2021)
		Environmental expenditure, €/1000 inhabitants	ENV3	2020	80898	2496	389125	INE (2021)
		Number of non-governmental organizations for the environment (transformation: divided by the total population)	ENV4	2020	0	0	0.0003	INE (2021)
ICT	Open data	Existence of local open data platforms (Yes=1, No=0)	ICT1	2022	0	0	1	Own observation
	Internet access	Fixed broadband internet access per 100 inhabitants	ICT2	2020	32.90	20.64	65.04	INE (2021)
Governance	Citizen participation	Abstention rate in municipal elections, %	G1	2021	39.83	22.2	59.9	INE (2021)
	Transparency	Municipal transparency index, ranging from 0 to 100	G2	2017	51.65	10.71	90.66	Transparency International Portugal (2017)

Source: Own elaboration

The chosen dimensions are, thus, according to the literature: living conditions (Abreu et al., 2020; Berrone & Ricart, 2020; Bosch et al., 2017; Cohen, 2014; Giffinger & Gudrun, 2010; IMD, 2021; INTELI & CEIIA, 2016; International Organization for Standardization, 2018; Xia Li et al., 2019; MMF, 2021; Reference Framework for Sustainable Cities, 2016); economy (Berrone & Ricart, 2020; Bosch et al., 2017; Cohen, 2014; Giffinger & Gudrun, 2010; International Organization for Standardization, 2018; Xia Li et al., 2019; MMF, 2021; Reference Framework for Sustainable Cities, 2016); transport and mobility (Albino et al., 2015; Berrone & Ricart, 2020; Bosch et al., 2017; Cohen, 2014; Giffinger & Gudrun, 2010; IMD, 2021; International Organization for Standardization, 2018; Xia Li et al., 2019; MMF, 2021; Reference Framework for Sustainable Cities, 2016; Shields & Langer, 2009); education and culture (Abreu et al., 2020; Berrone & Ricart, 2020; Cohen, 2014; Giffinger & Gudrun, 2010; International Organization for Standardization, 2018; Xia Li et al., 2019; Reference Framework for Sustainable Cities, 2016); environment (Abreu et al., 2020; Berrone & Ricart, 2020; Bosch et al., 2017; Cohen, 2014; European Commission, n.d.-a; Giffinger & Gudrun, 2010; IMD, 2021; INTELI & CEIIA, 2016; International Organization for Standardization, 2018; Xia Li et al., 2019; MMF, 2021; Reference Framework for Sustainable Cities, 2016; Shields & Langer, 2009); ICT (Berrone & Ricart, 2020; Bosch et al., 2017; Cohen, 2014; Giffinger & Gudrun, 2010; IMD, 2021; INTELI & CEIIA, 2016; International Organization for Standardization, 2018; Xia Li et al., 2019; Reference Framework for Sustainable Cities, 2016); governance (Berrone & Ricart, 2020; Bosch et al., 2017; Cohen, 2014; Giffinger & Gudrun, 2010; IMD, 2021; INTELI & CEIIA, 2016; International Organization for Standardization, 2018; Reference Framework for Sustainable Cities, 2016).

Since we collected the most recent data that was available for each indicator, the time period varies across our dataset, although most of it refers to 2020. The underlying assumption is that, although not all data refers to the same year, and that most of them is not from the current year either, the information we have still provides a consistent picture of a municipality's level of smart sustainability. In the case of the variable "Transparency", which is measured by Transparency International Portugal's Municipal Transparency Index, data refers to 2017. For the variables "Public transport network" and "Walkability", there were two particular datasets from the 2021 Census – "Proportion of employed and student population using collective mode of transport in commuting" and "Proportion of employed and student population using pedestrian mode of transport in commuting" – that would be of interest in this research but, as they are yet to become available to the public, data from the 2011

Census is instead used as a proxy here.

Since Portuguese cities differ in size and population, data must be scaled so that we can accurately compare them with each other, that is, data must be standardised. Furthermore, the indicators are not all measured in the same unit, which means that normalisation is also required. In that sense, we divided the data by the municipality's population or area whenever it was necessary (as some data was already standardised) and, afterwards, a min-max normalisation was conducted, so values vary between 0 and 1 (with 0 corresponding to the minimum and 1 to the maximum):

$$x_{i\ min-max} = \frac{x_i - \min(x)}{\max(x) - \min(x)}$$

with *x* being a given indicator, and *i* a given municipality.[2]

The next step was to evaluate whether some of the chosen indicators were redundant. In that sense, a Pearson correlation coefficient between each pair of indicators[3] was calculated (see Appendix 1). As the indicators "Expenditure on cultural heritage" and "Expenditure on cultural activities" were highly correlated and they were measuring the same variable, the decision to exclude "Expenditure on cultural heritage" was made. Although other indicators appeared to be highly correlated as well, they were kept in the index as they were deemed as non-redundant: the "Number of metro stations" is positively correlated to both the "Number of firemen" and "Number of non-governmental organizations for the environment", but this does not necessarily mean repeated information; instead, it is likely that this correlation stems purely from the fact that the municipalities with metro stations are the ones with higher population density (which explains the correlation of the "Number of metro stations" with the "Number of firemen per km^2") or it is simply coincidental. In the case of the "Gini coefficient of gross reported income less personal income paid tax per tax household" and "Local purchasing power per capita index", although they are both

[2] Since 4 of our indicators had, theoretically, a negative impact on a city's level of smart sustainability – this is the case of "Gini coefficient of gross reported income less personal income paid tax per tax household", "Consumption of motor fuel by inhabitant", "Registered unemployment" and "Abstention rate in municipal elections" -, for these we subtracted the normalized value to 1 so that a higher value would translate into a higher level of smart sustainability.

[3] Since the indicator "Number of local open data platforms" is a nominal variable, a point-biserial correlation (which is a special case of the Pearson correlation that is used to measure correlation between a dichotomous variable and a continuous variable) was used to measure the correlation between that indicator and the other ones.

included in the dimension "Living conditions", they measure two different variables - "Inequality" and "Purchasing Power" - that can provide two different pictures of the same municipality.

In composite indices, an important aspect is the weighting technique that is to be used. The first attempt is to pursue a more common approach, which is calculating a simple average of indicators and dimensions: first, we calculate a municipality's average score in each one of the 7 dimensions, then, its average, to get the smart sustainable city score for each municipality.

Constructing an index with equal weights for all dimensions (and, within each dimension, equal weights for all variables) may, however, not be the most accurate approach, as there can be overlapping information between two or more variables that are correlated with each other (OECD, 2008). With that in mind, we also conducted an exploratory factor analysis (EFA) using the principal component analysis (PCA) method[4], which is a multivariate analysis technique that studies the observed correlations between variables in order to estimate common unobserved factors that influence the variables; i.e., EFA allows us to identify structural relationships between variables that would have otherwise gone unnoticed (Field, 2009; Hair et al., 2014; Marôco, 2021).

EFA is an appropriate approach to determine the weights of our index, as it "groups together individual indicators which are collinear to form a composite indicator that captures as much as possible of the information common to individual indicators" (OECD, 2008, p. 89). This technique only makes sense if there is a significant correlation among variables, so we tested whether or not EFA was appropriate by computing the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, as initially proposed by Kaiser (1974). Since we have obtained a value of 0.81 – which is deemed as "meritorious" (Kaiser, 1974) -, EFA is thus considered adequate.

According to the OECD (2008, p. 89), the individual indicators should be grouped into the "smallest possible number of factors" while accounting for "the highest variation in the indicator set". When choosing the number of factors, the most common approach is Kaiser's criterion, which implies choosing the factors that have an eigenvalue equal or larger than one (Field, 2009). Although there are other possible criteria (OECD, 2008) to apply - that would, in turn, lead to a different choice of number of factors - , there is evidence that

[4] The software used was IBM SPSS Statistics 27.

Kaiser's criterion is accurate by itself for sample sizes larger than 250 and an average communality equal or larger than 0.6, which is our case (see Appendix 2). As shown in Table 4, that leads us to the choice of 7 factors.

The weights were determined by the matrix of factor loadings after rotation (Table 5), since "the square of factor loadings represents the proportion of the total unit variance of the indicator which is explained by the factor" (OECD, 2008, p. 90). Within each group, the weight of each indicator was calculated by dividing the squared sum of factor loadings by the variance that is explained by that factor (its eigenvalue); then, the weight of each factor was calculated by dividing its eigenvalue by the sum of the 7 eigenvalues.

Table 4: Exploratory Factor Analysis – Variance matrix

Component	Initial eigenvalues			Extraction Sum of Squared Loadings			Rotation sum of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	6,066	24,265	24,265	6,066	24,265	24,265	4,257	17,027	17,027
2	3,068	12,271	36,537	3,068	12,271	36,537	3,137	12,548	29,575
3	1,908	7,630	44,167	1,908	7,630	44,167	3,034	12,135	41,710
4	1,536	6,143	50,310	1,536	6,143	50,310	1,693	6,771	48,481
5	1,219	4,875	55,185	1,219	4,875	55,185	1,321	5,285	53,766
6	1,141	4,564	59,749	1,141	4,564	59,749	1,285	5,142	58,907
7	1,018	4,072	63,821	1,018	4,072	63,821	1,228	4,913	63,821
8	0,991	3,963	67,783						
9	0,883	3,533	71,316						
10	0,808	3,232	74,548						
11	0,778	3,112	77,660						
12	0,709	2,834	80,494						
13	0,675	2,700	83,194						
14	0,585	2,338	85,532						
15	0,566	2,263	87,796						
16	0,540	2,160	89,956						
17	0,498	1,993	91,949						
18	0,400	1,601	93,550						
19	0,372	1,486	95,036						
20	0,329	1,317	96,352						
21	0,296	1,184	97,536						
22	0,211	0,846	98,382						
23	0,201	0,804	99,186						
24	0,124	0,497	99,683						
25	0,079	0,317	100,000						

Source: Own elaboration

Table 5: Exploratory Factor Analysis – Factor loadings after rotation

Variable	Indicators	Factor loadings							Squared factor loading (scaled to unity sum)						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Inequality	LC1	**-0,679**	-0,380	0,014	0,248	-0,019	-0,043	0,111	**0,108**	0,046	0,000	0,036	0,000	0,001	0,010
Purchasing Power	LC2	**0,734**	0,474	-0,082	0,177	0,263	0,008	-0,026	**0,127**	0,072	0,002	0,018	0,052	0,000	0,001
Quality of water	LC3	**0,386**	0,062	-0,163	0,281	-0,334	-0,249	0,071	**0,035**	0,001	0,009	0,047	0,084	0,048	0,004
Healthcare	LC4	0,476	**0,552**	-0,076	0,058	0,290	0,057	0,096	0,053	**0,097**	0,002	0,002	0,064	0,003	0,008
Competitiveness	ECO1	-0,219	-0,118	-0,185	-0,105	0,129	-0,193	**0,757**	0,011	0,004	0,011	0,007	0,013	0,029	**0,467**
Entrepreneurial ecosystem	ECO2	**0,626**	0,220	0,327	-0,247	-0,187	0,061	0,026	**0,092**	0,015	0,035	0,036	0,027	0,003	0,001
Unemployment	ECO3	-0,065	-0,070	-0,244	**0,615**	0,103	0,422	0,042	0,001	0,002	0,020	**0,223**	0,008	0,139	0,001
R&D	ECO4	-0,381	-0,094	**0,724**	-0,015	-0,146	-0,127	0,177	0,034	0,003	**0,173**	0,000	0,016	0,013	0,026
Low-carbon emission transport	TM1	-0,020	-0,016	0,018	**-0,519**	0,023	0,227	0,286	0,000	0,000	0,000	**0,159**	0,000	0,040	0,067
	TM2	0,098	0,180	**0,637**	0,133	0,213	-0,015	-0,093	0,002	0,010	**0,134**	0,010	0,034	0,000	0,007
Public transport network	TM3	0,188	**0,798**	0,041	-0,043	0,083	-0,007	-0,039	0,008	**0,203**	0,001	0,001	0,005	0,000	0,001
	TM4	-0,266	**0,519**	-0,309	-0,374	-0,273	0,051	-0,292	0,017	**0,086**	0,032	0,083	0,056	0,002	0,069
Walkability	TM5	-0,087	-0,136	**0,642**	-0,197	0,102	-0,514	0,114	0,002	0,006	**0,136**	0,023	0,008	0,205	0,011
Student ICT Access	EDU1	**0,521**	-0,059	-0,367	-0,041	-0,062	0,032	-0,265	**0,064**	0,001	0,044	0,001	0,003	0,001	0,057
School enrolment	EDU2	0,101	0,129	0,164	0,015	**0,798**	-0,049	0,019	0,002	0,005	0,009	0,000	**0,482**	0,002	0,000
Tertiary education	EDU3	**0,734**	0,488	-0,150	0,162	0,118	0,144	-0,011	**0,127**	0,076	0,007	0,016	0,011	0,016	0,000
Cultural activities	EDU4	-0,088	-0,053	**0,683**	0,019	0,051	-0,093	0,043	0,002	0,001	**0,154**	0,000	0,002	0,007	0,002
Waste management	ENV1	-0,005	-0,020	0,095	**0,732**	-0,045	0,016	0,091	0,000	0,000	0,003	**0,317**	0,002	0,000	0,007
Environmental protection	ENV2	0,251	**0,785**	-0,100	-0,022	0,120	-0,034	-0,056	0,015	**0,197**	0,003	0,000	0,011	0,001	0,003
	ENV3	0,004	-0,075	**0,675**	-0,076	0,008	0,123	-0,117	0,000	0,002	**0,150**	0,003	0,000	0,012	0,011
	ENV4	-0,081	0,131	0,276	0,137	-0,341	0,161	**0,531**	0,002	0,005	0,025	0,011	0,088	0,020	**0,229**
Open data	ICT1	0,144	**0,713**	0,060	0,004	-0,115	0,019	0,057	0,005	**0,162**	0,001	0,000	0,010	0,000	0,003
Internet access	ICT2	**0,842**	0,111	0,095	0,022	0,159	0,016	-0,088	**0,167**	0,004	0,003	0,000	0,019	0,000	0,006

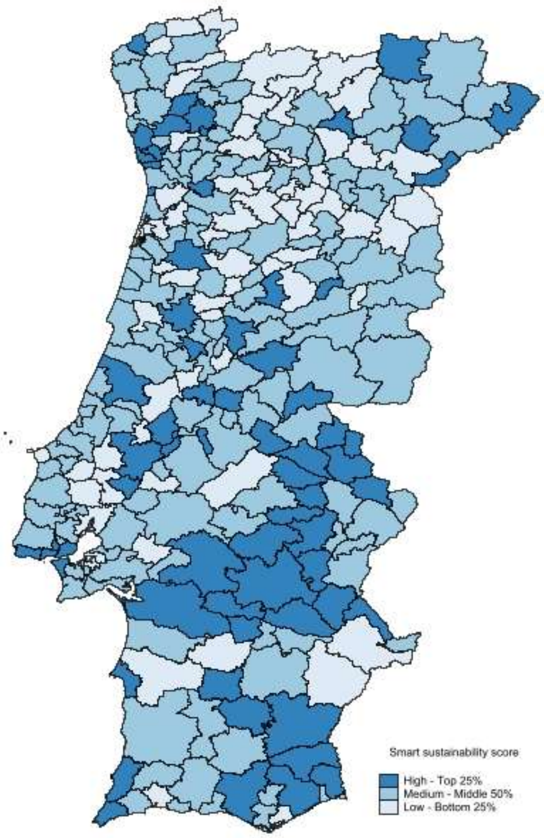
Variable	Indicators	Factor loadings							Squared factor loading (scaled to unity sum)						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Abstention	G1	**-0,728**	-0,064	0,370	-0,084	0,077	-0,038	0,114	**0,124**	0,001	0,045	0,004	0,005	0,001	0,011
Transparency	G2	0,104	0,006	-0,050	-0,054	-0,035	**0,766**	-0,034	0,003	0,000	0,001	0,002	0,001	**0,456**	0,001
Explained Variance		**4,257**	**3,137**	**3,034**	**1,693**	**1,321**	**1,285**	**1,228**							
Total Explained Variance		**0,267**	**0,197**	**0,190**	**0,106**	**0,083**	**0,081**	**0,077**							

Source: Own elaboration

3.3. Smart sustainable city levels in Portugal – results and discussion

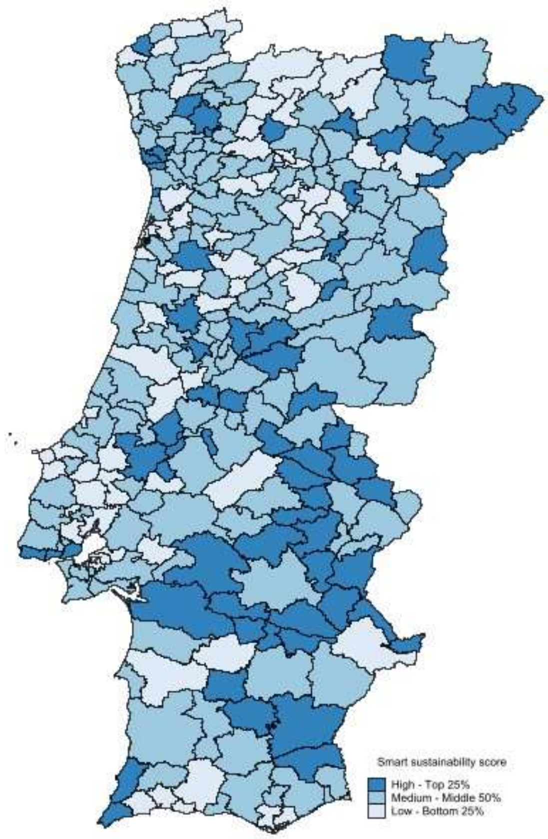
The assessment of smart sustainable urban development in Portuguese cities was made considering two approaches: a simple average of variables and dimensions (results can be found in Appendix 3 and are briefly depicted in Figure 1) and an exploratory factor analysis (see Appendix 4 and Figure 2).

Figure 1 – Smart sustainable city index, using a simple average[5]



Source: Own elaboration

Figure 2 - Smart sustainable city index, using EFA[5]



Source: Own elaboration

[5] The software used for the elaboration of these maps was StataSE 17, with the add-ons spmap and shp2dta. The shapefiles of the Portuguese municipalities were retrieved from the European Environmental Agency website: https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2/gis-files/portugal-shapefile.

Using the simple average approach, the municipalities with the highest scores are Lisboa, Porto, Oeiras, Vila do Bispo and Cascais (see full ranking results in Appendix 3, respectively. A score is considered "High" when it is a part of the top 25% of all scores, whereas it is considered "Low" when it is in the bottom 25% - a "Medium" score is, thus, part of the middle 50% of the sample. That implies that the comparison among municipalities is always done in relative terms within the sample, i.e., a municipality having a "High" score only means it performs well when compared to the Portuguese panorama of smart sustainable urban development[6].

Looking at Figure 1, we can conclude that the Northern region displays lower levels of smart sustainability, when compared to the Centre or South, except for part of the Northwest (in the districts of Porto and Braga) and some municipalities in the Northeast (in the district of Bragança). Another important observation is the fact that, although the two largest cities (Lisboa and Porto) are among the top 5, municipalities in the countryside appear to perform well, even though they tend to be smaller and mostly rural.

Using the EFA approach, the top 5 municipalities are now Lisboa, Porto, Oeiras, São João da Madeira and Constância, respectively (full ranking results can be found in Appendix 4). Looking at the whole Portuguese panorama of smart sustainable urban development (Figure 2), one can see that the conclusions are similar as the ones drawn for the simple average index - the Centre and South regions display higher levels in general, and countryside municipalities appear to perform better than coastal ones -, although visual differences can be found, for instance, in the North (the districts of Porto and Braga do not display such high levels of smart sustainability anymore, whereas the Trás-os-Montes region appears stronger now).

In visual terms, it appears that the simple average and EFA methods yield similar results, although it is still possible to observe some differences in rankings. For instance, just by looking at the top 5, one can see that only 3 municipalities are on that list for both methods. That being said, it is important to test whether there are substantial differences in rankings when we use EFA as opposed to a simple average. The Wilcoxon signed-rank test, which tests whether two related samples are different from one another (Marôco, 2021), was then conducted on the municipality rankings obtained under the simple average and the EFA,

[6] In order to assess a municipality's score absolute value more accurately, it would be necessary to have a reference value for all indicators being considered, so that we could compare a municipality's performance in each indicator to that reference.

with a p-value of 0.884. For any significance level, we do not reject the null hypothesis that the samples are equal, so we can conclude that both methods yield the same results.

Our results are somewhat similar to the ones obtained by the already existing index of Portuguese smart cities (INTELI & CEIIA, 2016), with Porto, Cascais and Guimarães being featured in the top 10 of both. Still, the differences in rankings can be explained by the fact that INTELI and CEIIA (2016) use a much smaller sample of Portuguese municipalities. Furthermore, the theoretical approach used by them is different from ours (there is a much larger focus on theoretically "smart" aspects of a city, such as ICT, and dimensions such as transport and mobility are not considered), and the dataset is also not the same (as they use less recent data and work with survey data as well).

4. Finding out the determinants of smart sustainable cities

The final objective of this dissertation is to assess the determinants of smart sustainable cities, as our main goal is to understand why some cities are more "smart sustainable" than others in Portugal. In section 4.1. we will then create the model behind this analysis, whose results are later presented and discussed in section 4.2.

4.1. The model

After constructing and calculating the index for all 278 Portuguese municipalities, the next step is to use the results for each city (the "score") as a dependent variable and test the impact of potential explanatory variables on that score. This estimation makes use of cross-sectional data, so the econometric model is estimated as an ordinary least squares (OLS) multivariate linear regression and can be described as follows:

$$\boldsymbol{y_i = \beta_0 + \beta X_i + u_i}$$

with *i* representing the municipality (i=1, 2, …, 278). y_i is the smart sustainable city score for municipality *i* using EFA, X_i is the vector of explanatory variables for municipality *i*, β is the vector of coefficients associated to those explanatory variables and u_i is the error term for municipality *i*.

Taking into account the previously mentioned existing literature on the determinants of smart sustainable cities (Akande et al., 2019; Bosch et al., 2017; Neirotti et al., 2014; Nevado Gil et al., 2020), as well as other works that consider more general insights on what influences local government decisions (da Cruz & Marques, 2014), we can divide the explanatory variables into 4 dimensions: demographic, institutional, economic sectors and spatial. Given the importance of institutional factors in the process of local decision-making, variables within this group are further divided into 2 sub-dimensions: economic and governance. With that in mind, we collected additional data from INE as well as from the Portuguese General Secretary of the Ministry of Internal Administration (SGMAI), using the most recent data available[7]. More information regarding the indicators used as well as its descriptive

[7] An exception to this rule is the indicator "Nights spent in tourist accommodations per 100 inhabitants", for which data from 2020 was available – due to the strong impact of the COVID-19 pandemic in that year, we chose to use data from 2019 instead. Similarly, we have also used 2017 data for the "Most voted political party, coalition or citizen group in municipal elections", since parties elected in 2021 would not have already had an impact on a municipality's smart sustainable city initiatives.

statistics can be found in Table 6.

A first step to construct the model was to look at the correlation coefficients between the variables, since highly correlated variables may result in inaccurate parameter estimates (Verbeek, 2017). From that analysis (which can be found in Appendix 5), we can already exclude the indicator "Single person private households, according to the Census (%)", since there is already another indicator for the variable "Household size" with which is highly correlated. Furthermore, the variables "Tourism", "Taxes" and "Immigrants" are highly correlated among each other, as it is the case between the variables "Ageing" and "Debt". Taking that into account and keeping all dimensions as well-represented as possible in the model, we decided to estimate the model with the pair "Ageing" and "Immigrants" and the pair "Ageing" and "Taxes".

The variable "Ideology", which is measured by "Results in the elections for the City Hall: elected individuals by political party, coalition or citizens group", can also be adapted for simpler interpretation, by grouping the original 9 different possibilities of political parties/coalitions into 3 political groups: left-wing, right-wing, and independent. The distribution of political parties among these groups can be found in Table 7.

Table 6: Dimensions and variables used in the model: descriptive statistics

Dimension	Sub-dimension	Variable	Indicator	Abbreviation	Year	Mean	Min.	Max.	Source
Demographic		Population density	Average number of individuals per km2	D1	2021	305,12	4,4	7211,9	INE (2021)
		Ageing	Ageing index	D2	2021	272,4	108,5	780,1	INE (2021)
		Immigrant share	Foreign population with legal resident status as a % of the resident population	D3	2020	4,6	0,4	43,2	INE (2021)
		Household size	Average household size, according to the Census	D4	2011	2,5	2,1	3,1	INE (2021)
			*Single person private households, according to the Census (%)**	D5	2021	25,6	13,9	40,3	INE (2021)
Institutional	**Economic**	*Debt level*	*Municipal councils' debt per inhabitant (€/inhabitant)**	IE1	2019	533,78	5	5977	INE (2021)
		Transfers	Current and capital transfers received by town councils (thousands €)	IE2	2019	11641,4	3403,38	60526,2	INE (2021)
		Taxes	Town council tax revenue per capita	IE3	2019	206,02	79,1	1098,8	INE (2021)
		Regional GDP per capita	GDP per capita, NUTS III (€)	IE4	2020	17295,1	12310	24922,4	INE (2021)
	Governance	Ideology	Most voted political party, coalition or citizen group in municipal elections	IG1-10	2017				SGMAI (2017)
		Government size	Number of mandates (seats) in the City Hall	IG11	2017	7	5	17	INE (2017)
Economic sectors		Primary sector	Enterprises in the primary sector (agriculture, farming of animals, hunting, forestry, fishing, mining, and quarrying) as a % of total enterprises	F1	2020	10,94	1,8	34,2	INE (2022)
		Manufacturing sector	Enterprises in the manufacturing sector as a % of total enterprises	F2	2020	12,18	0,24	60,9	INE (2022)
		Tourism	*Nights spent in tourist accommodations per 100 inhabitants**	F3	2019	546,58	7,4	20636	INE (2021)
Spatial		Area	Area (km²)	S1	2020	320,51	7,94	1720,6	INE (2021)
		City	City classification (1=Yes, 0=No)	S2	2020				INE (2021)
		Metropolitan Area	Belonging to a metropolitan area (1= Yes, 0=No)	S3	2022				INE (2022)

Note: Variables/indicators in italic ended up being excluded from the model, due to being highly correlated with other indicators.

Source: Own elaboration

Table 7: Political parties

Political party	European Parliament party/movement affiliation[8]	Orientation
PS	European Socialist Party	Left
PCP-PEV	European Green Party	Left
LIVRE + PS	Democracy in Europe Movement 2025 + European Socialist Party	Left
PPD/PSD	European People's Party	Right
CDS-PP	European People's Party	Right
PPD/PSD + CDS-PP + others	European People's Party	Right
Nós, Cidadãos!	N/A	Right
Independent	N/A	Independent

Source: Own elaboration

4.2. What determines a smart sustainable city?

A total of 4 versions of the model was estimated, with the results being displayed in Table 8 – models I and III consider the 9 political parties, whereas models II and IV consider the 3 political groups only. Since heteroskedasticity was present for all of them, we corrected it by using robust standard errors.

At a first glance, it is possible to see that all models are globally statistically significant, as illustrated by the F-statistic.

For a significance level of 0.10, all demographic variables are statistically significant in all models. Population density is always associated to positive coefficients, meaning that the more densely populated a municipality is, the higher its level of smart sustainability, which is line with Neirotti et al. (2014). Another variable that positively impacts a municipality's score is the immigrant share, which is an interesting finding that is not yet present in the literature of the determinants of smart sustainable cities, but has been previously observed for the broader case of regional development (Florida, Mellander, & Stolarick, 2008). Ageing and household size are, on the other hand, associated with lower levels of smart sustainability.

Looking at the institutional economic variables, we observe that a municipality's revenue, which consists of both its received transfers and taxes, has a positive impact on its

[8] In this table, we present each party's corresponding European political party/movement for the purpose of better understanding its ideology, although it is important to note that some of the parties and coalitions we consider in our sample are not actually represented in the European Parliament.

smart sustainability score. This is in line with the literature (Akande et al., 2019; Bosch et al., 2017; Neirotti et al., 2014) and it is also easy to understand - the more money a municipality receives, the more it can make investments in smart sustainable projects.

In what regards the institutional governance variables, it appears that the government size has no impact on the score. Since the government size (measured by the number of mandates in the City Hall) is related to the population of the municipality, this finding goes in line with the previous observation – the municipalities with higher levels of smart sustainability appear to be of both large and small dimension, so total population appears to not play a role in determining the smart sustainable city score.

Ideology variables – the parties in models I and III, and the political groups in models II and IV - have all negative coefficients. As the control group is the independent political party/group, this tells us that governments without a political party affiliation are associated to higher level of smart sustainable urban development - more than half of the municipalities with this type of government have a "High" score (Table 9 and Table 10). The governments affiliated to a political party, on the other hand, mostly display a "Medium" score - a fact observed for all political parties in our sample -, both left- and right-wing (Table 9 and Table 10). This corroborates the findings of Nevado Gil et al. (2020), who have stated that a local government's political orientation does not have an impact on the municipality's smart sustainable city level. The positive results of the independent government tell us, however, that, although ideology itself may not play a role, a government not being affiliated to any political party may actually be a determining factor in a municipality becoming more "smart and sustainable".

Looking at the economic sector variables, it is possible to observe that the relative importance of the manufacturing sector in a municipality's economic activity is positively associated to the smart sustainable city score, which is not mentioned in the existing literature. This might be related with economic variables, as manufacturing is positively correlated to per capita income, the share of exports in total trade and the number of business births. The primary sector, on the other hand, appears to have no impact on the level of smart sustainable urban development.

Finally, if we take a look at the three spatial variables considered in the models - the municipality's area, its classification as a city and it belonging or not to a metropolitan area - , the conclusion that none of this has an impact on the smart sustainable city score can be drawn. In fact, the observation that both large and small cities can display high levels of smart sustainability has been made both throughout this work already and by Neirotti et al. (2014). Nevertheless, it is interesting to see that, in particular, it does not even matter if a municipality does not have the Portuguese requirements to be considered a "city" (note that this is a functional criterion).

Table 8: The determinants of smart sustainable cities – Ordinary Least Squares

Dependent variable = Smart sustainable city score (EFA)						
Dimension	Variable	Abbreviation	I	II	III	IV
Demographic	Population density	D1	0.0000142** (0.000)	0.0000141** (0.010)	0.0000136** (0.021)	0.0000134** (0.021)
	Ageing	D2	-0.0000386* (0.068)	-0.0000365* (0.079)	-0.0000417* (0.053)	-0.0000402* (0.056)
	Immigrant share	D3			0.000514* (0.068)	0.000512* (0.059)
	Household size	D4	-0.0293*** (0.006)	-0.0279*** (0.008)	-0.0319*** (0.006)	-0.0305*** (0.007)
Institutional	Transfers	IE2	0.0295*** (0.000)	0.0294*** (0.000)	0.0288*** (0.000)	0.0287*** (0.000)
	Taxes	IE3	0.0000326** (0.010)	0.0000326*** (0.009)		
	Regional GDP per capita	IE4	-0.000000783 (0.240)	-0.000000738 (0.232)	-0.000000807 (0.255)	-0.000000730 (0.256)
	Ideology = CDS-PP	IG1	-0.0160 (0.125)		-0.0166 (0.123)	
	Ideology = LIVRE + PS	IG3	-0.0351*** (0.000)		-0.0346*** (0.001)	
	Ideology = Nós, Cidadãos!	IG4	-0.0295*** (0.000)		-0.0312*** (0.000)	
	Ideology = PCP-PEV	IG5	-0.0184** (0.013)		-0.0183** (0.019)	
	Ideology = PPD/PSD	IG6	-0.0206*** (0.003)		-0.0215*** (0.004)	
	Ideology = PPD/PSD + CDS-PP + others	IG7	-0.0152** (0.046)		-0.0157* (0.054)	
	Ideology = PS	IG8	-0.0166** (0.015)		-0.0177** (0.014)	
	Ideology = Left	IG9		-0.0169** (0.012)		-0.0179** (0.012)
	Ideology = Right	IG10		-0.0195*** (0.004)		-0.0203*** (0.005)
	Government size	IG11	0.00259 (0.241)	0.00269 (0.207)	0.00288 (0.222)	0.00299 (0.186)
Economic sector	Primary sector	F1	0.0212 (0.296)	0.0214 (0.278)	0.0172 (0.395)	0.0181 (0.363)
	Manufacturing sector	F2	0.0944*** (0.001)	0.0938*** (0.001)	0.0865*** (0.003)	0.0812*** (0.003)
Spatial	Area	S1	0.00000196 (0.748)	0.00000135 (0.820)	0.000000326 (0.959)	-7.29e-08 (0.991)
	City	S2	-0.00233 (0.503)	-0.00214 (0.534)	-0.00204 (0.560)	-0.00186 (0.591)
	Metropolitan Area	S3	0.000887 (0.811)	0.00102 (0.781)	0.000467 (0.900)	0.000568 (0.876)
Constant			0.249*** (0.000)	0.244*** (0.000)	0.263*** (0.000)	0.258*** (0.000)
N			278	278	278	278
R-sq			0.442	0.438	0.431	0.426

Note: p-values in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Source: Own elaboration

Table 9: Contingency table – Political party by smart sustainable city level, using the EFA score

			Smart sustainable city level			Total
			High	**Medium**	**Low**	
Political party	**CDS-PP**	**Count**	0	3	1	4
		%	0%	75%	25%	100%
	Independent	**Count**	8	4	3	15
		%	53,33%	26,67%	20%	100%
	LIVRE/PS	**Count**	0	1	0	1
		%	0%	100%	0%	100%
	Nós, Cidadãos!	**Count**	0	0	1	1
		%	0%	0%	100%	100%
	PCP-PEV	**Count**	7	13	3	23
		%	30,43%	56,52%	13,04%	100%
	PPD/PSD	**Count**	15	35	23	73
		%	20,55%	47,95%	31,51%	100%
	PPD/PSD, CDS-PP and others	**Count**	3	10	5	18
		%	16,67%	55,56%	27,78%	100%
	PS	**Count**	36	74	33	143
		%	25,17%	51,75%	23,08%	100%
Total		**Count**	69	140	69	278
		%	24,82%	50,36%	24,82%	100%

Source: Own elaboration

Table 10: Contingency table – Political group by smart sustainable city level, using the EFA score

			Smart sustainable city level			Total
			High	**Medium**	**Low**	
Political group	**Independent**	**Count**	8	4	3	15
		%	53,33%	20%	26,67%	100%
	Left	**Count**	43	88	36	167
		%	25,75%	52,69%	21,56%	100%
	Right	**Count**	18	48	30	96
		%	18,75%	50%	31,25%	100%
	Total	**Count**	69	140	69	278
		%	24,82%	50,36%	24,82%	100%

Source: Own elaboration

Chapter 5. Conclusions

In face of today's challenges, municipalities around the world need to make efforts towards becoming more sustainable, namely through "smart" investments not only in ICT but also in human capital. Aside from understanding what a smart sustainable city is, it is important to understand what factors determine a municipality's level of smart sustainable development, so that policymakers are able to implement the most adequate policies. After the definition of "smart sustainable city", the objectives of this work were to assess the level of smart sustainable urban development of Portuguese municipalities and, based on that, find out the determinants of such urban development.

The assessment of smart sustainable urban development in Portugal was done through the creation of a composite index, that includes 7 dimensions: living conditions, economy, transport and mobility, education and culture, environment, ICT, governance. We used two different weighting techniques – a simple average and one based on exploratory factor analysis -, which yielded similar results in terms of municipality rankings.

Our index showed that the Northern region in Portugal displays lower levels of smart sustainability, when compared to the Centre or South, expect for the Northwest (in the disctricts of Porto and Braga). In addition, although the two largest cities (Lisboa and Porto) are among the top 5, municipalities in the countryside appear to perform well.

Afterwards, the level of smart sustainability obtained by each municipality through the index using EFA (also known as the "score") was used in the construction of an econometric model aimed at finding out the determinants of smart sustainable cities, using ordinary least squares. Data was cross-sectional and it was grouped into 5 types of determinants: demographic, institutional economic, institutional governance, economic sectors, spatial.

An important takeaway from both the index scores and the econometric model results is that a municipality's size does not matter when it comes to the decision to become more "smart sustainable". In fact, out of the top 10 municipalities, only 5 of them are classified as cities. Furthermore, although absolute population does not seem to play a role either, population density was shown to have a positive impact on the smart sustainable city score. All of these results had already been observed in the literature, too (Neirotti et al., 2014).

Another relevant conclusion is related to the institutional (economic and governance) variables in our model, to which we put particular emphasis on since, according to the literature, this type of variables is the most important one when determining local government decisions and investments (Nevado Gil et al., 2020). What we conclude is that, on the one hand, a municipality's revenues have a positive effect on its level of smart sustainability (the more money they receive, the more "smart sustainable" they are, on average); on the other hand, ideology, in particular left- versus right-wing orientation, does not have an impact on the score. These conclusions had already been taken in the literature as well (Nevado Gil et al., 2020), but our work provides a contribution by presenting a new result: municipalities with an "independent" government (that is, a local government that is not affiliated with a national party) present higher levels of smart sustainability, suggesting that the lack of affiliation may be associated to a higher interest in smart sustainable city projects and investments.

Some other variables such as the ageing of the population or the share of immigrants residing in the municipality also have a non-null impact on the smart sustainable city score – an older population is associated with lower levels, and a higher percentage of immigrants with higher ones. The latter is in line with the work of Florida et al. (2008), who found out the importance of immigrants for a city's creative class and concluded they are the key to economic growth and development. Furthermore, it has also been observed that the average household size is negatively correlated with smart sustainable urban development.

As one of the main conclusions was that independent local governments perform better in terms of smart sustainability, this work suggests that policymakers that are affiliated to a national party should learn from the independents' best practices. On a different sphere, policies that tackle demographic issues would also be relevant – since the larger households are associated to lower levels of smart sustainability, social measures such as family discounts and bundles (which have already been applied in the case of public transportation in the metropolitan areas of Porto and Lisboa) are also important for boosting smart sustainable city development. Furthermore, it is important that policymakers invest in the acquisition of more funds to be applied in smart sustainable city projects, considering the opportunity that arises from the European structural funds (European Commission, n.d.-b), which promote sustainable urban and regional development and cover dimensions such as the economy, the environment, transport and mobility.

There are some limitations in our work, namely due to the lack of access to some data, either because it was not available yet (2021 Census) or because it would require a much more meticulous and slower collection process (through direct inquiries to municipalities, for example, which would nevertheless imply a lower coverage of Portuguese municipalities). This problem arises because we are specifically dealing with all mainland Portuguese municipalities, for which there is not an extensive database – that being said, similar research conducted for other, likely larger cities would probably be easier. It is also important to mention that some characteristics of the municipalities are not distributed evenly across the sample, as it is the case of the "independent" governments – there are only 9 municipalities out of 278 with this characteristic, which may weaken our conclusion that this type of government leads to higher levels of smart sustainability.

We suggest that our work is replicated for different samples, as well as for different time periods, to validate and strengthen (or not) our findings. Future research could also test for a different type of determinant, the "neighbourhood effect" which, although not directly mentioned in the studies on the determinants of smart sustainable cities, is associated to the gravity models (Nijkamp & Ratajczak, 2021) and hypothesises that a city's smart sustainable level is correlated with level of its neighbours.

References

Abreu, J., António, J. H. C., & Cerol, J. (2020). *Índice de Sustentabilidade Municipal 2020*. Retrieved from Lisbon: https://www.local2030.org/library/view/818

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities, 60*, 234-245. doi:10.1016/j.cities.2016.09.009

Akande, A., Cabral, P., Gomes, P., & Casteleyn, S. (2019). The Lisbon ranking for smart sustainable cities in Europe. *Sustainable Cities and Society, 44*, 475-487. doi:10.1016/j.scs.2018.10.009

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology, 22*(1), 3-21. doi:10.1080/10630732.2014.942092

Berrone, P., & Ricart, J. E. (2020). *IESE Cities in Motion Index 2020*. Retrieved from https://www.ieseinsight.com/fichaMaterial.aspx?pk=74436&idi=2

Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. (2017). *CITYkeys indicators for smart city projects and smart cities*. Retrieved from https://nws.eurocities.eu/MediaShell/media/CITYkeystheindicators.pdf

Camagni, R., Capello, R., & Nijkamp, P. (1998). Towards sustainable city policy: an economy-environment technology nexus. *Ecological Economics, 24*(1), 103-118. doi:10.1016/s0921-8009(97)00032-3

Caragliu, A., Del Bo, C., & Nijkamp, P. (2009). Smart Cities in Europe. *VU University Amsterdam, Faculty of Economics, Business Administration and Econometrics, Serie Research Memoranda, 18*. doi:10.1080/10630732.2011.601117

Cohen, B. (2014). Smart City Index Master Indicators Survey. Retrieved from https://www.smartcitiescouncil.com/resources/smart-city-index-master-indicators-survey. https://www.smartcitiescouncil.com/resources/smart-city-index-master-indicators-survey

Correia, D., Teixeira, L., & Marques, J. L. (2021). Reviewing the State-of-the-Art of Smart Cities in Portugal: Evidence Based on Content Analysis of a Portuguese Magazine. *Publications, 9*(4), 49. doi:10.3390/publications9040049

da Cruz, N. F., & Marques, R. C. (2014). Revisiting the determinants of local government performance. *Omega, 44*, 91-103. doi:https://doi.org/10.1016/j.omega.2013.09.002

Dijkstra, L., & Poelman, H. (2012). *Cities in Europe: the new OECD-EC definition*. Retrieved from https://ec.europa.eu/regional_policy/sources/docgener/focus/2012_01_city.pdf

European Commission. (n.d.-a). European Green Capital. Retrieved from https://ec.europa.eu/environment/europeangreencapital/applying-for-the-award/evaluation-process/

European Commission. (n.d.-b). European structural and investment funds. Retrieved from https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en

Field, A. (2009). *Discovering Statistics Using SPSS*. London: SAGE.

Florida, R., Mellander, C., & Stolarick, K. (2008). Inside the black box of regional development - human capital, the creative class and tolerance. *Journal of Economic Geography, 8*(5), 615-649. doi:10.1093/jeg/lbn023

Giffinger, R., & Gudrun, H. (2010). Smart cities ranking: an effective instrument for the positioning of the cities? *ACE: Architecture, City and Environment, 4*(12), 7-26. doi:10.5821/ace.v4i12.2483

González, J. A., & Rossi, A. (2011). *New trends for smart cities*. Retrieved from https://cordis.europa.eu/docs/projects/cnect/6/270896/080/deliverables/001-D2221NewtrendsforSmartCities.pdf
Hair, J., Black, W., Babin, B., & Anderson, R. (2014). *Multivariate data analysis* (7 ed.). Harlow: Pearson.
Hatuka, T., Rosen-Zvi, I., Birnhack, M., Toch, E., & Zur, H. (2018). The Political Premises of Contemporary Urban Concepts: The Global City, the Sustainable City, the Resilient City, the Creative City, and the Smart City. *Planning Theory & Practice, 19*(2), 160-179. doi:10.1080/14649357.2018.1455216
Hiremath, R. B., Balachandra, P., Kumar, B., Bansode, S. S., & Murali, J. (2013). Indicator-based urban sustainability—A review. *Energy for Sustainable Development, 17*(6), 555-563. doi:10.1016/j.esd.2013.08.004
Höjer, M., & Wangel, J. (2015). Smart Sustainable Cities: Definition and Challenges. In (pp. 333-349): Springer International Publishing.
Hollands, R. G. (2008). Will the real smart city please stand up? *City, 12*(3), 303-320. doi:10.1080/13604810802479126
Huovila, A., Bosch, P., & Airaksinen, M. (2019). Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when? *Cities, 89*, 141-153. doi:10.1016/j.cities.2019.01.029
IMD. (2021). *Smart City Index 2021*. Retrieved from https://www.imd.org/smart-city-observatory/home/
INTELI, & CEIIA. (2016). *Smart City Index Portugal*. Retrieved from https://docs.wixstatic.com/ugd/e565ce_2e2ca4a79e854fdc9a36ab7a65a6669b.pdf
International Organization for Standardization. (2018). ISO 37120:2018(en) Sustainable cities and communities — Indicators for city services and quality of life. Retrieved from https://www.iso.org/obp/ui/#iso:std:68498:en
International Telecommunications Union. (2016). *Overview of key performance indicators in smart sustainable cities*. Retrieved from https://www.itu.int/itu-t/recommendations/rec.aspx?rec=12627
Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika, 39*(1), 31-36. doi:10.1007/bf02291575
Li, X., Li, X., Woetzel, J., Zhang, G., & Zhang, Y. (2014). *Urban Sustainability Index 2013*. Retrieved from http://www.mckinseychina.com/wp-content/uploads/2014/04/china-urban-sustainability-index-2013.pdf
Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J. K., Thaarup, R. K., . . . Kotterink, B. (2014). *Mapping smart cities in the EU*. Retrieved from Brussel: http://resolver.tudelft.nl/uuid:1fac0e18-8dd3-406d-86fe-ce1e6a22e90c
Marôco, J. (2021). *Análise Estatística com o SPSS Statistics*. Pêro Pinheiro: Report Number.
Martin, C. J., Evans, J., & Karvonen, A. (2018). Smart and sustainable? Five tensions in the visions and practices of the smart-sustainable city in Europe and North America. *Technological Forecasting and Social Change, 133*, 269-278. doi:https://doi.org/10.1016/j.techfore.2018.01.005
Ministry of Environment, Spatial Planning and Energy,. (2015). *SUSTAINABLE CITIES 2020*. Retrieved from https://www.forumdascidades.pt/sites/default/files/sustainablecities_2020_eng.pdf

MMF. (2021). *Global Power City Index 2021*. Retrieved from https://mori-m-foundation.or.jp/pdf/GPCI2021_summary.pdf

Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. *Cities, 38*, 25-36. doi:10.1016/j.cities.2013.12.010

Nevado Gil, M. T., Carvalho, L., & Paiva, I. (2020). Determining factors in becoming a sustainable smart city: An empirical study in Europe. *Economics and Sociology, 13*(1), 24-39. doi:10.14254/2071-789X.2020/13-1/2

Nijkamp, P., & Perrels, A. (2014). *Sustainable Cities in Europe*: Routledge.

Nijkamp, P., & Ratajczak, W. (2021). Gravitational Analysis in Regional Science and Spatial Economics: A Vector Gradient Approach to Trade. *International Regional Science Review, 44*(3-4), 400-431. doi:10.1177/0160017620980519

OECD. (2008). *Handbook on Constructing Composite Indicators*. Retrieved from

Pira, M. (2021). A novel taxonomy of smart sustainable city indicators. *Humanities and Social Sciences Communications, 8*(1). doi:10.1057/s41599-021-00879-7

Piro, G., Cianci, I., Grieco, L. A., Boggia, G., & Camarda, P. (2014). Information centric services in Smart Cities. *Journal of Systems and Software, 88*, 169-188. doi:10.1016/j.jss.2013.10.029

Reference Framework for Sustainable Cities. (2016). 5 dimensions and 30 objectives for a European vision of tomorrow's cities. Retrieved from http://rfsc.eu/wp-content/uploads/2016/03/30-objectives-1.pdf

Rodrigues, M., & Franco, M. (2020). Measuring the urban sustainable development in cities through a Composite Index: The case of Portugal. *Sustainable Development, 28*(4), 507-520. doi:10.1002/sd.2005

Shields, K., & Langer, H. (2009). *European Green City Index*. Retrieved from https://assets.new.siemens.com/siemens/assets/api/uuid:fddc99e7-5907-49aa-92c4-610c0801659e/european-green-city-index.pdf

Stanickova, M., & Melecký, L. (2018). Understanding of resilience in the context of regional development using composite index approach: the case of European Union NUTS-2 regions. *Regional Studies, Regional Science, 5*(1), 231-254. doi:10.1080/21681376.2018.1470939

U4SSC. (2017). *Collection Methodology for Key Performance Indicators for Smart Sustainable Cities*. Retrieved from

United Nations. (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*. Retrieved from https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

United Nations. (2020). *Sustainable cities: why they matter*. Retrieved from https://www.un.org/sustainabledevelopment/wp-content/uploads/2019/07/11_Why-It-Matters-2020.pdf

Verbeek, M. (2017). *A guide to modern econometrics*. New Jersey: Wiley Custom.

World Commission on Environment and Development. (1987). *Our Common Future*. Retrieved from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Yigitcanlar, T., Kamruzzaman, M., Foth, M., Sabatini-Marques, J., Da Costa, E., & Ioppolo, G. (2019). Can cities become smart without being sustainable? A systematic review of the literature. *Sustainable Cities and Society, 45*, 348-365. doi:10.1016/j.scs.2018.11.033

Zygiaris, S. (2013). Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems. *Journal of the Knowledge Economy,* *4*(2), 217-231. doi:10.1007/s13132-012-0089-4

Annexes

Appendix 1: Correlation coefficients – variables in the smart sustainable city index

	LC1	**LC2**	**LC3**	**LC4**	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**TM1**	**TM2**	**TM3**	**TM5**	**TM6**	**EDU1**	**EDU2**	**EDU3**	**EDU4**	**EDU5**	**(…)**
LC1	1.00																		
LC2	-0.61	1.00																	
LC3	-0.12	0.27	1.00																
LC4	-0.55	0.67	0.13	1.00															
ECO1	0.26	-0.20	-0.04	-0.15	1.00														
ECO2	-0.55	0.39	0.11	0.30	-0.18	1.00													
ECO3	0.16	0.07	0.07	-0.00	-0.01	-0.19	1.00												
ECO4	0.26	-0.44	-0.18	-0.28	0.09	-0.04	-0.20	1.00											
TM1	-0.03	-0.12	-0.07	0.00	0.07	0.06	-0.11	0.10	1.00										
TM2	-0.12	0.19	-0.01	0.11	-0.13	0.20	-0.06	0.34	-0.05	1.00									
TM3	-0.40	0.50	0.08	0.51	-0.14	0.31	-0.08	-0.13	0.01	0.13	1.00								
TM5	-0.12	-0.04	-0.01	0.04	-0.09	0.02	-0.13	-0.20	0.09	-0.15	0.30	1.00							
TM6	0.10	-0.18	-0.11	-0.17	0.08	0.06	-0.44	0.62	0.06	0.30	-0.06	-0.27	1.00						
EDU1	-0.33	0.36	0.22	0.16	-0.19	0.14	0.06	-0.43	-0.04	-0.14	0.09	0.08	-0.28	1.00					
EDU2	-0.11	0.28	-0.07	0.23	0.00	0.05	-0.02	-0.06	-0.05	0.25	0.16	-0.15	0.17	-0.00	1.00				
EDU3	-0.70	0.86	0.27	0.76	-0.25	0.42	0.13	-0.43	-0.04	0.10	0.47	0.03	-0.33	0.37	0.13	1.00			
EDU4	0.16	-0.10	-0.10	-0.08	-0.03	0.14	-0.08	0.45	0.01	0.31	0.02	-0.21	0.46	-0.27	0.10	-0.19	1.00		
EDU5	0.12	-0.10	-0.06	-0.06	-0.04	0.03	-0.10	0.41	0.02	0.27	-0.02	-0.17	0.39	-0.21	0.07	-0.15	0.72	1.00	
(…)																			

	LC1	LC2	LC3	LC4	ECO1	ECO2	ECO3	ECO4	TM1	TM2	TM3	TM5	TM6	EDU1	EDU2	EDU3	EDU4	EDU5	(…)
ENV1	0.17	0.05	0.09	0.02	-0.05	-0.10	0.28	0.13	-0.13	0.04	-0.04	-0.30	-0.03	-0.06	-0.01	0.09	-0.02	-0.02	
ENV2	-0.41	0.61	0.15	0.46	-0.12	0.26	-0.08	-0.24	0.01	0.10	0.64	0.33	-0.12	0.18	0.21	0.56	-0.13	-0.12	
ENV3	0.06	-0.09	-0.13	-0.14	-0.07	0.16	-0.16	0.38	0.02	0.30	-0.03	-0.13	0.3	-0.18	0.12	-0.13	0.34	0.30	
ENV4	0.11	-0.09	-0.03	-0.04	0.14	0.07	0.02	0.26	-0.07	0.09	0.01	-0.03	0.08	-0.14	-0.03	-0.07	0.14	0.06	
ICT1	-0.34	0.39	0.10	0.34	-0.08	0.27	-0.08	-0.11	0.01	0.13	0.47	0.21	-0.09	0.03	0.05	0.39	-0.05	-0.06	
ICT2	-0.49	0.72	0.25	0.41	-0.22	0.51	-0.05	-0.33	-0.07	0.19	0.30	-0.15	-0.05	0.36	0.23	0.65	-0.04	-0.03	
G1	0.50	-0.57	-0.25	-0.31	0.21	-0.30	-0.08	0.57	0.09	0.16	-0.19	0.00	0.34	-0.45	0.03	-0.58	0.30	0.23	
G2	-0.09	0.09	0.04	0.06	-0.12	0.03	0.10	-0.13	0.03	-0.06	0.06	0.04	-0.29	0.12	-0.02	0.13	-0.13	-0.03	

	ENV1	ENV2	ENV3	ENV4	ICT1	ICT2	G1	G2
ENV1	1.00							
ENV2	-0.02	1.00						
ENV3	0.02	-0.07	1.00					
ENV4	0.05	-0.04	0.10	1.00				
ICT1	-0.01	0.49	0.03	0.07	1.00			
ICT2	-0.02	0.33	0.14	-0.10	0.20	1.00		
G1	-0.05	-0.30	0.22	0.13	-0.15	-0.59	1.00	
G2	-0.02	0.08	-0.03	0.00	0.04	0.09	-0.11	1.00

Source: Own elaboration

Appendix 2: Exploratory Factor Analysis - Communalities

Variable	Communalities after extraction
LC1	0,681
LC2	0,872
LC3	0,636
LC4	0,437
ECO1	0,734
ECO2	0,648
ECO3	0,637
ECO4	0,747
TM1	0,404
TM2	0,520
TM3	0,685
TM4	0,738
TM5	0,764
EDU1	0,487
EDU2	0,693
EDU3	0,861
EDU4	0,491
ENV1	0,556
ENV2	0,709
ENV3	0,496
ENV4	0,542
ICT1	0,549
ICT2	0,764
G1	0,698
G2	0,605

Source: Own elaboration

Appendix 3: Ranking of smart sustainable city scores of Portuguese municipalities – simple average method

Municipality	Ranking	Smart sustainable city score
Lisboa	1	0.580
Porto	2	0.543
Oeiras	3	0.468
Vila do Bispo	4	0.438
Cascais	5	0.437
Castelo de Vide	6	0.411
Guimarães	7	0.406
Alcoutim	8	0.401
Constância	9	0.400
Golegã	10	0.398
Manteigas	11	0.395
Miranda do Douro	12	0.391
Aljezur	13	0.390
Góis	14	0.387
Vila Velha de Ródão	15	0.387
São João da Madeira	16	0.387
Arronches	17	0.386
Viana do Alentejo	18	0.385
Coimbra	19	0.383
Murça	20	0.382
Alfândega da Fé	21	0.382
Crato	22	0.382
Águeda	23	0.378
Alter do Chão	24	0.374
Vizela	25	0.369
Mértola	26	0.369
Vila Nova de Cerveira	27	0.368
Montemor-o-Novo	28	0.367
Penela	29	0.366
Portalegre	30	0.366
Loulé	31	0.365
Mourão	32	0.365
Vila de Rei	33	0.364
Braga	34	0.363
Amadora	35	0.363
Tavira	36	0.362
Santarém	37	0.359
Ferreira do Zêzere	38	0.359
Fronteira	39	0.358
Alcácer do Sal	40	0.357
Alvito	41	0.356
Torres Novas	42	0.356
Gavião	43	0.355
Aljustrel	44	0.355
Oliveira do Hospital	45	0.355
Redondo	46	0.355
Leiria	47	0.354
Estremoz	48	0.354
Castro Marim	49	0.354
Matosinhos	50	0.353
Arraiolos	51	0.353
Portel	52	0.353
Vinhais	53	0.352
Castro Verde	54	0.352
Maia	55	0.352
Vila Nova de Famalicão	56	0.352
Entroncamento	57	0.351
Sousel	58	0.351
Almada	59	0.350
Freixo de Espada à Cinta	60	0.348
Vila do Conde	61	0.348
Évora	62	0.348
Cartaxo	63	0.347
Oleiros	64	0.346
Castelo de Paiva	65	0.345
Espinho	66	0.345
Marvão	67	0.345
Sines	68	0.344
Reguengos de Monsaraz	69	0.344
Mafra	70	0.343
Viseu	71	0.343

Alpiarça	72	0.343
Vidigueira	73	0.343
Alandroal	74	0.342
Sardoal	75	0.342
Porto de Mós	76	0.341
São Brás de Al-portel	77	0.340
Cuba	78	0.339
Vale de Cambra	79	0.339
Ourique	80	0.339
Tábua	81	0.339
Albufeira	82	0.338
Barreiro	83	0.338
Barrancos	84	0.337
Trofa	85	0.337
Paços de Ferreira	86	0.336
Lousada	87	0.336
Covilhã	88	0.335
Elvas	89	0.335
Batalha	90	0.335
Penamacor	91	0.334
Guarda	92	0.334
Aveiro	93	0.334
Monforte	94	0.333
Monchique	95	0.333
Vimioso	96	0.333
Penalva do Castelo	97	0.332
Beja	98	0.332
Grândola	99	0.331
Fornos de Algo-dres	100	0.331
Mogadouro	101	0.330
Albergaria-a-Velha	102	0.330
Figueira da Foz	103	0.329
Sesimbra	104	0.329
Vila Flor	105	0.329
Odivelas	106	0.328
Vouzela	107	0.328
Mondim de Ba-sto	108	0.327
Paredes	109	0.327
Sintra	110	0.326
Pampilhosa da Serra	111	0.326
Lagos	112	0.326
Arruda dos Vin-hos	113	0.326
Castelo Branco	114	0.326
Póvoa de Varzim	115	0.326
Chamusca	116	0.326
Bragança	117	0.325
Nazaré	118	0.325
Seixal	119	0.324
Fundão	120	0.324
Vila Real	121	0.323
Castanheira de Pêra	122	0.323
Torres Vedras	123	0.323
Mealhada	124	0.323
Benavente	125	0.323
Penafiel	126	0.323
Arouca	127	0.323
Vendas Novas	128	0.323
Lousã	129	0.322
Idanha-a-Nova	130	0.321
Marinha Grande	131	0.321
Avis	132	0.321
Valongo	133	0.321
Penedono	134	0.320
São João da Pesqueira	135	0.320
Borba	136	0.320
Ovar	137	0.320
Palmela	138	0.320
Amares	139	0.319
Aguiar da Beira	140	0.319
Almodôvar	141	0.319
Salvaterra de Magos	142	0.319
Alcobaça	143	0.319
Mirandela	144	0.319
Silves	145	0.319
Baião	146	0.318
Fafe	147	0.318
Odemira	148	0.318
Macedo de Cavaleiros	149	0.318
Nisa	150	0.318
Mação	151	0.317

Arcos de Valdevez	152	0.317
Lagoa	153	0.317
Viana do Castelo	154	0.317
Carregal do Sal	155	0.316
Armamar	156	0.316
Caldas da Rainha	157	0.316
Sabrosa	158	0.315
Alcochete	159	0.315
Mortágua	160	0.314
Sertã	161	0.314
Ponte de Lima	162	0.314
Arganil	163	0.314
Marco de Canaveses	164	0.314
Sever do Vouga	165	0.314
Vila Real de Santo António	166	0.313
Mora	167	0.313
Soure	168	0.313
Miranda do Corvo	169	0.313
Vila Viçosa	170	0.313
Óbidos	171	0.312
Vagos	172	0.312
Vila Nova da Barquinha	173	0.312
Gondomar	174	0.312
Sobral de Monte Agraço	175	0.311
Almeida	176	0.311
Mesão Frio	177	0.311
Setúbal	178	0.311
Bombarral	179	0.311
Terras de Bouro	180	0.311
Figueiró dos Vinhos	181	0.310
Valença	182	0.310
Condeixa-a-Nova	183	0.310
Ansião	184	0.310
Vila Nova de Foz Côa	185	0.309
Faro	186	0.309
Barcelos	187	0.309
Campo Maior	188	0.308
Gouveia	189	0.308

Vila Pouca de Aguiar	190	0.308
Felgueiras	191	0.308
Proença-a-Nova	192	0.308
Celorico da Beira	193	0.308
Póvoa de Lanhoso	194	0.307
Mira	195	0.307
Sabugal	196	0.307
Tomar	197	0.305
Mêda	198	0.305
Coruche	199	0.304
Loures	200	0.304
Lamego	201	0.304
Cantanhede	202	0.304
Ílhavo	203	0.303
Abrantes	204	0.301
Lourinhã	205	0.301
Caminha	206	0.300
Pombal	207	0.300
Vieira do Minho	208	0.300
Vila Nova de Gaia	209	0.300
Vila Franca de Xira	210	0.298
Alcanena	211	0.298
Pedrógão Grande	212	0.298
Vila Nova de Poiares	213	0.297
Ponte de Sor	214	0.297
Esposende	215	0.297
Penacova	216	0.297
Santa Comba Dão	217	0.296
Santo Tirso	218	0.295
Belmonte	219	0.295
Cinfães	220	0.294
Estarreja	221	0.294
Peniche	222	0.293
Vila Verde	223	0.293
São Pedro do Sul	224	0.293
Santa Marta de Penaguião	225	0.293
Figueira de Castelo Rodrigo	226	0.292
Montemor-o-Velho	227	0.292

Ourém	228	0.291
Alijó	229	0.291
Azambuja	230	0.291
Oliveira de Azeméis	231	0.290
Murtosa	232	0.290
Portimão	233	0.290
Alvaiázere	234	0.290
Oliveira de Frades	235	0.290
Cabeceiras de Basto	236	0.289
Anadia	237	0.289
Sernancelhe	238	0.287
Pinhel	239	0.286
Rio Maior	240	0.286
Moimenta da Beira	241	0.286
Trancoso	242	0.285
Oliveira do Bairro	243	0.284
Montijo	244	0.284
Castro Daire	245	0.284
Torre de Moncorvo	246	0.283
Seia	247	0.283
Montalegre	248	0.283
Monção	249	0.282
Olhão	250	0.282
Ferreira do Alentejo	251	0.280
Almeirim	252	0.280
Alenquer	253	0.279
Paredes de Coura	254	0.279
Santa Maria da Feira	255	0.279
Valpaços	256	0.279
Serpa	257	0.278
Mangualde	258	0.277
Tabuaço	259	0.277
Cadaval	260	0.276
Carrazeda de Ansiães	261	0.275
Ponte da Barca	262	0.275
Nelas	263	0.274
Boticas	264	0.273
Chaves	265	0.273
Amarante	266	0.272
Moura	267	0.270
Ribeira de Pena	268	0.270
Tondela	269	0.270
Santiago do Cacém	270	0.268
Moita	271	0.266
Tarouca	272	0.266
Celorico de Basto	273	0.264
Sátão	274	0.263
Peso da Régua	275	0.262
Melgaço	276	0.261
Resende	277	0.261
Vila Nova de Paiva	278	0.257

Source: Own elaboration

Appendix 4: Ranking of smart sustainable city scores of Portuguese municipalities – EFA method

Municipality	Ranking	Smart sustainable city score
Lisboa	1	0.37
Porto	2	0.347
Oeiras	3	0.277
São João da Madeira	4	0.265
Constância	5	0.264
Manteigas	6	0.263
Vila Velha de Ródão	7	0.259
Alfândega da Fé	8	0.257
Miranda do Douro	9	0.255
Góis	10	0.253
Arronches	11	0.252
Castelo de Vide	12	0.251
Alcoutim	13	0.248
Cascais	14	0.248
Barrancos	15	0.24
Crato	16	0.24
Golegã	17	0.24
Vila do Bispo	18	0.239
Freixo de Espada à Cinta	19	0.238
Gavião	20	0.238
Alter do Chão	21	0.238
Mértola	22	0.237
Viana do Alentejo	23	0.237
Vizela	24	0.237
Castro Verde	25	0.235
Guimarães	26	0.233
Mogadouro	27	0.231
Oleiros	28	0.23
Vinhais	29	0.23
Murça	30	0.23
Mourão	31	0.229
Redondo	32	0.229
Vila de Rei	33	0.228
Coimbra	34	0.227
Vila Nova de Cerveira	35	0.227
Vimioso	36	0.223
Aljustrel	37	0.223
Montemor-o-Novo	38	0.222
Penela	39	0.222
Santarém	40	0.221
Espinho	41	0.221
Reguengos de Monsaraz	42	0.221
Portel	43	0.221
Entroncamento	44	0.22
Torres Novas	45	0.22
Ferreira do Zêzere	46	0.22
Aljezur	47	0.219
Penedono	48	0.219
Braga	49	0.219
Sousel	50	0.219
Portalegre	51	0.218
Vidigueira	52	0.217
Matosinhos	53	0.217
Águeda	54	0.217
Fronteira	55	0.216
Penamacor	56	0.216
Alpiarça	57	0.216
Estremoz	58	0.215
Pampilhosa da Serra	59	0.215
Alcácer do Sal	60	0.215
Almeida	61	0.215
Alandroal	62	0.214
Cuba	63	0.214
Alvito	64	0.213
Fornos de Algodres	65	0.213
Maia	66	0.213
Arraiolos	67	0.213
Mondim de Basto	68	0.213
Vila Flor	69	0.213
Sardoal	70	0.212

Vila Nova de Famalicão	71	0.212
Castanheira de Pêra	72	0.212
Mesão Frio	73	0.212
Oliveira do Hospital	74	0.211
Avis	75	0.211
Penalva do Castelo	76	0.211
Ourique	77	0.21
Almada	78	0.208
Évora	79	0.208
Elvas	80	0.208
Bragança	81	0.207
Macedo de Cavaleiros	82	0.207
Amadora	83	0.207
Mirandela	84	0.206
Vila Nova de Foz Côa	85	0.206
Odivelas	86	0.206
Cartaxo	87	0.205
Castro Marim	88	0.205
Vouzela	89	0.205
Leiria	90	0.204
São João da Pesqueira	91	0.204
Aveiro	92	0.204
Monchique	93	0.203
Vila Nova da Barquinha	94	0.203
Vale de Cambra	95	0.203
Beja	96	0.202
Tábua	97	0.202
Borba	98	0.202
Monforte	99	0.201
Guarda	100	0.201
Chamusca	101	0.201
Tavira	102	0.201
Loulé	103	0.201
Arganil	104	0.201
Mora	105	0.201
Arouca	106	0.2
Vila do Conde	107	0.2
Porto de Mós	108	0.2
Vendas Novas	109	0.2

Barreiro	110	0.2
Paços de Ferreira	111	0.2
Figueiró dos Vinhos	112	0.2
Celorico da Beira	113	0.199
Sabrosa	114	0.199
Sever do Vouga	115	0.199
Fundão	116	0.199
Castelo de Paiva	117	0.199
Marvão	118	0.199
Vila Viçosa	119	0.198
São Brás de Alportel	120	0.198
Sines	121	0.198
Pedrógão Grande	122	0.198
Covilhã	123	0.198
Viseu	124	0.198
Odemira	125	0.198
Lousã	126	0.197
Trofa	127	0.197
Santo Tirso	128	0.197
Almodôvar	129	0.196
Campo Maior	130	0.196
Figueira da Foz	131	0.195
Proença-a-Nova	132	0.195
Baião	133	0.195
Arruda dos Vinhos	134	0.195
Albergaria-a-Velha	135	0.195
Mêda	136	0.194
Grândola	137	0.194
Belmonte	138	0.194
Mação	139	0.194
Coruche	140	0.194
Terras de Bouro	141	0.193
Gouveia	142	0.193
Benavente	143	0.192
Figueira de Castelo Rodrigo	144	0.192
Póvoa de Varzim	145	0.192
Carregal do Sal	146	0.192
Castelo Branco	147	0.192

Arcos de Valdevez	148	0.191
Mortágua	149	0.191
Tomar	150	0.191
Aguiar da Beira	151	0.191
Tabuaço	152	0.19
Nisa	153	0.19
Batalha	154	0.19
Sertã	155	0.19
Lousada	156	0.19
Alcobaça	157	0.19
Mealhada	158	0.189
Póvoa de Lanhoso	159	0.189
Salvaterra de Magos	160	0.189
Fafe	161	0.189
Ovar	162	0.189
Penafiel	163	0.189
Armamar	164	0.188
Valença	165	0.188
Mira	166	0.188
Idanha-a-Nova	167	0.188
Seixal	168	0.188
Viana do Castelo	169	0.188
Miranda do Corvo	170	0.188
Marinha Grande	171	0.187
Felgueiras	172	0.187
Paredes	173	0.187
Setúbal	174	0.186
Ansião	175	0.186
Soure	176	0.186
Cantanhede	177	0.186
Amares	178	0.186
Vila Pouca de Aguiar	179	0.186
Mafra	180	0.186
Lamego	181	0.186
Valongo	182	0.186
Sintra	183	0.185
Albufeira	184	0.185
Palmela	185	0.184
Gondomar	186	0.184
Vila Real de Santo António	187	0.184

Vila Nova de Poiares	188	0.183
Caldas da Rainha	189	0.183
Castro Daire	190	0.183
Vagos	191	0.183
Vieira do Minho	192	0.183
Barcelos	193	0.182
São Pedro do Sul	194	0.182
Sabugal	195	0.182
Torres Vedras	196	0.182
Marco de Canaveses	197	0.182
Serpa	198	0.181
Ponte de Lima	199	0.181
Sesimbra	200	0.181
Alcanena	201	0.181
Condeixa-a-Nova	202	0.181
Trancoso	203	0.181
Bombarral	204	0.181
Pinhel	205	0.181
Vila Real	206	0.18
Vila Nova de Gaia	207	0.18
Abrantes	208	0.18
Alijó	209	0.18
Ponte de Sor	210	0.18
Almeirim	211	0.18
Estarreja	212	0.18
Monção	213	0.179
Penacova	214	0.179
Melgaço	215	0.179
Carrazeda de Ansiães	216	0.179
Sernancelhe	217	0.179
Torre de Moncorvo	218	0.179
Valpaços	219	0.178
Pombal	220	0.178
Moura	221	0.178
Vila Verde	222	0.178
Faro	223	0.178
Moimenta da Beira	224	0.177
Alvaiázere	225	0.177
Ourém	226	0.176

Ribeira de Pena	227	0.176
Nazaré	228	0.176
Alcochete	229	0.176
Sobral de Monte Agraço	230	0.176
Santa Comba Dão	231	0.175
Silves	232	0.174
Ílhavo	233	0.174
Oliveira de Azeméis	234	0.174
Ferreira do Alentejo	235	0.174
Montalegre	236	0.174
Lagoa	237	0.174
Lagos	238	0.174
Loures	239	0.173
Oliveira de Frades	240	0.173
Esposende	241	0.173
Anadia	242	0.172
Ponte da Barca	243	0.173
Cabeceiras de Basto	244	0.172
Paredes de Coura	245	0.172
Montemor-o-Velho	246	0.17
Rio Maior	247	0.17
Caminha	248	0.17
Seia	249	0.17
Tondela	250	0.17
Cinfães	251	0.169
Vila Franca de Xira	252	0.169
Azambuja	253	0.168
Boticas	254	0.168
Santa Marta de Penaguião	255	0.168
Santa Maria da Feira	256	0.168
Sátão	257	0.168
Oliveira do Bairro	258	0.167
Olhão	259	0.167
Peniche	260	0.167
Nelas	261	0.167
Lourinhã	262	0.166
Óbidos	263	0.166
Vila Nova de Paiva	264	0.166
Mangualde	265	0.164
Murtosa	266	0.164
Chaves	267	0.164
Amarante	268	0.162
Tarouca	269	0.162
Montijo	270	0.161
Peso da Régua	271	0.158
Celorico de Basto	272	0.156
Santiago do Cacém	273	0.156
Alenquer	274	0.155
Cadaval	275	0.154
Portimão	276	0.152
Resende	277	0.151
Moita	278	0.149

Source: Own elaboration

Appendix 5: Correlation coefficients – explanatory variables

	D1	D2	D3	D4	D5	IE1	IE2	IE3	IE4	IG1	IG2	IG3	IG4	IG5	IG6	IG7	IG8	IG9	IG10	IG11	(…)
D1	1.00																				
D2	0.27	1.00																			
D3	0.18	-0.19	1.00																		
D4	0.01	-0.58	-0.28	1.00																	
D5	-0.00	0.65	0.26	-0.92	1.00																
IE1	-0.12	0.16	-0.02	-0.11	0.16	1.00															
IE2	-0.33	0.76	-0.20	-0.51	0.58	0.21	1.00														
IE3	0.21	-0.30	0.80	-0.14	0.11	0.04	-0.35	1.00													
IE4	0.44	-0.35	0.45	-0.14	0.09	-0.17	-0.30	0.42	1.00												
IG1	-0.02	-0.07	-0.04	0.14	-0.15	-0.05	-0.07	-0.03	0.04	1.00											
IG2	0.14	-0.08	-0.05	0.06	-0.07	-0.06	-0.07	0.01	0.03	-0.03	1.00										
IG3	0.01	-0.06	-0.04	0.14	-0.14	-0.03	-0.05	-0.03	-0.10	-0.01	-0.01	1.00									
IG4	-0.02	-0.03	-0.01	0.08	-0.05	-0.02	0.00	-0.03	-0.04	-0.01	-0.01	-0.00	1.00								
IG5	-0.04	-0.14	0.02	-0.11	0.08	-0.05	-0.02	0.08	0.28	-0.04	-0.07	-0.02	-0.02	1.00							
IG6	-0.13	0.25	-0.08	-0.05	0.10	0.00	0.16	-0.08	-0.20	-0.07	-0.14	-0.04	-0.04	-0.18	1.00						
IG7	0.05	-0.13	0.02	0.21	-0.19	0.00	-0.14	0.07	-0.00	-0.03	-0.06	-0.02	-0.02	-0.08	-0.16	1.00					
IG8	0.06	-0.02	0.09	-0.08	0.05	0.07	-0.00	0.00	0.02	-0.12	-0.25	-0.06	-0.06	-0.31	-0.61	-0.27	1.00				
IG9	0.04	-0.10	0.10	-0.13	0.08	0.03	-0.02	0.05	0.17	-0.15	-0.29	0.05	-0.07	0.24	-0.73	-0.32	0.84	1.00			
IG10	-0.10	0.14	-0.08	0.11	-0.05	-0.00	0.05	-0.05	-0.19	0.17	-0.17	-0.04	0.08	-0.22	0.82	0.36	-0.75	-0.89	1.00		
IG11	0.63	-0.50	0.14	0.31	-0.34	-0.24	-0.68	0.28	0.43	0.01	0.04	0.07	-0.06	0.02	-0.17	0.18	0.02	0.04	-0.06	1.00	
(…)																					

	D1	D2	D3	D4	D5	IE1	IE2	IE3	IE4	IG1	IG2	IG3	IG4	IG5	IG6	IG7	IG8	IG9	IG10	IG11	(…)
F1	-0.31	0.30	-0.15	-0.39	0.40	0.12	0.61	-0.26	-0.19	-0.08	-0.01	-0.05	0.00	0.21	-0.06	-0.14	0.03	0.14	-0.15	-0.53	
F2	-0.13	0.06	-0.39	0.41	-0.43	-0.05	-0.01	-0.39	-0.25	0.18	0.07	0.25	0.01	-0.17	0.02	-0.01	-0.02	-0.09	0.06	-0.03	
F3	0.04	-0.10	0.66	-0.12	0.12	0.09	-0.11	0.70	0.15	-0.03	-0.03	-0.02	-0.01	-0.02	0.06	0.00	-0.02	-0.03	0.05	0.02	
S1	-0.26	0.25	0.07	-0.36	0.37	-0.07	0.22	-0.03	-0.03	-0.06	-0.09	-0.04	-0.04	0.25	-0.07	-0.10	0.04	0.18	-0.14	-0.11	
S2	0.27	-0.36	0.11	0.20	-0.23	-0.08	-0.54	0.20	0.15	0.08	0.08	0.07	-0.05	0.00	-0.10	0.09	-0.01	0.00	-0.03	0.56	
S3	-0.05	-0.07	-0.06	0.07	-0.06	-0.03	-0.05	-0.06	-0.04	-0.05	0.00	-0.02	-0.02	0.00	-0.05	-0.01	0.07	0.07	-0.07	0.00	

	F1	F2	F3	S1	S2	S3
F1	1.00					
F2	-0.20	1.00				
F3	-0.12	-0.28	1.00			
S1	0.42	-0.22	-0.03	1.00		
S2	-0.35	0.08	0.10	0.09	1.00	
S3	0.00	0.01	-0.06	0.07	0.08	1.00

Source: Own elaboration

Appendix 6: Contingency table – Political party by smart sustainable city level, using the simple average score

			Smart sustainable city level			Total
			High	Medium	Low	
Political party	CDS-PP	Count	0	3	1	4
		%	0%	75%	25%	100%
	Independent	Count	9	3	3	15
		%	60%	20%	20%	100%
	LIVRE/PS	Count	0	1	0	1
		%	0%	100%	0%	100%
	Nós, Cidadãos!	Count	0	0	1	1
		%	0%	0%	100%	100%
	PCP-PEV	Count	5	16	2	23
		%	21,74%	69,57%	8,7%	100%
	PPD/PSD	Count	12	42	19	73
		%	16,44%	57,53%	26,03%	100%
	PPD/PSD, CDS-PP and others	Count	5	6	7	18
		%	27,78%	33,33%	38,89%	100%
	PS	Count	38	69	36	143
		%	26,57%	48,25%	25,17%	100%
Total		Count	69	140	69	278
		%	24,82%	50,36%	24,82%	100%

Source: Own elaboration

Appendix 7: Contingency table – Political group by smart sustainable city level, using the simple average score

			Smart sustainable city level			Total
			High	**Medium**	**Low**	
Political group	**Independent**	**Count**	9	3	3	15
		%	60%	20%	20%	100%
	Left	**Count**	43	86	38	167
		%	25,75%	51,5%	22,75%	100%
	Right	**Count**	17	51	28	96
		%	17,71%	53,13%	29,17%	100%
Total		**Count**	69	140	69	278
		%	24,82%	50,36%	24,82%	100%

Source: Own elaboration