**T.C.**

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# THE IMPACT OF SMART CITIES ON URBAN SUSTAINABILITY: A STUDY OF THE WORLD'S SMARTEST CITIES

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# ABSTRACT


**THE IMPACT OF SMART CITIES ON URBAN SUSTAINABILITY:**
**A STUDY OF THE WORLD'S SMARTEST CITIES**
**TARA VANLI**

In the age of the digital revolution, many cities around the world have made significant investments in planning and implementing smart city initiatives to cope with economic and environmental challenges posed by modern-day complex city systems. However, despite their promising solutions, there is little evidence of how smart city initiatives can achieve urban sustainability. This research hypothesises that overcoming economic and environmental challenges with a smart city framework entails a systematic approach to increasing synergies and eliminating trade-offs between different smart city drivers. It then explores the impact of smartness on urban sustainability by introducing the concept of smart complementarity and investigating whether the systemic governance of smart complementarities positively impacts sustainability.

To this end, the research first applies network analysis and uses data from 33 smart cities worldwide from 2005–2019 to ascertain these synergies and trade-offs by introducing a modified framework of smart cities based on the community identification of interconnected smart city drivers. Thereafter, the research employs a panel vector autoregression (PVAR) model with panel data for 26 smart cities from 2009-2019 to test the complex dynamic relationships between smart city drivers and dimensions of sustainability. Such analysis seems crucial for smart city governance and whether the vision of a smart agenda is compatible with urban sustainability.

In addition, a static and dynamic ranking of 33 selected cities for the period 2005-2019 is provided using dynamic factor analysis. In this comparative study, cities are evaluated and ranked on various smart drivers, including technology, community, infrastructure, community, and governance, to identify the best (and worst) smart city and to highlight the changes in

smartness over the last 15 years. The results of this analysis can serve as an empirical basis for identifying specific strengths and weaknesses of cities and as a knowledge-based decision-making tool for policymakers and metropolitan leaders in selecting policies that can improve the growth and performance of smart cities.

The findings of this research reveal that only a few trade-offs exist in the network of smart city indicators compared to the identified synergies. Furthermore, the network statistics show that innovation, business sophistication, ICT infrastructure, and government effectiveness are key drivers of a smart city. In addition, findings suggest that while smart city initiatives have improved economic sustainability, they have compromised environmental and social sustainability. This points to the need for a coordinated approach to address the complexity of urban systems and sustainability challenges. Finally, the research recommends several proposals to steer the efforts of policymakers and the private and public sectors towards more effective and efficient strategic planning and implementation of smart city initiatives.

**Keywords:** Smart city; urban development; smart policy; urban sustainability, complementarity, governance; ranking, indicators, network analysis; dynamic factor analysis; PVAR.

# ÖZ

## AKILLI ŞEHİRLERİN KENTSEL SÜRDÜRÜLEBİLİRLİK ÜZERİNDEKİ ETKİSİ: DÜNYANIN EN AKILLI ŞEHİRLERİ ARAŞTIRMASI

**TARA VANLI**

Dijital devrim çağında, dünyadaki birçok şehir, modern karmaşık şehir sistemlerinin ortaya çıkardığı ekonomik ve çevresel zorluklarla başa çıkmak için akıllı şehir girişimlerinin planlanması ve uygulanmasına önemli yatırımlar yaptı. Bununla birlikte, umut verici çözümlerine rağmen, akıllı şehir girişimlerinin kentsel sürdürülebilirliği nasıl sağlayabileceğine dair çok az kanıt var. Bu araştırma, bir akıllı şehir çerçevesiyle ekonomik ve çevresel zorlukların üstesinden gelmenin, sinerjileri artırmaya ve farklı akıllı şehir sürücüleri arasındaki değiş tokuşları ortadan kaldırmaya yönelik sistematik bir yaklaşım gerektirdiğini varsaymaktadır. Ardından, akıllı tamamlayıcılık kavramını tanıtarak ve akıllı tamamlayıcılıkların sistemik yönetişiminin sürdürülebilirliği olumlu yönde etkileyip etkilemediğini araştırarak akıllılığın kentsel sürdürülebilirlik üzerindeki etkisini araştırıyor.

Bu amaçla, araştırma ilk olarak ağ analizini uygular ve birbirine bağlı akıllı şehir sürücülerinin topluluk tanımlamasına dayalı olarak değiştirilmiş bir akıllı şehirler çerçevesi sunarak bu sinerjileri ve ödünleşimleri tespit etmek için 2005-2019 yılları arasında dünya çapında 33 akıllı şehirden alınan verileri kullanır. Daha sonra araştırma, akıllı şehir sürücüleri ile sürdürülebilirliğin boyutları arasındaki karmaşık dinamik ilişkileri test etmek için 2009-2019 yılları arasında 26 akıllı şehir için panel verili bir panel vektör otoregresyon (PVAR) modeli kullanır. Bu tür analizler, akıllı şehir yönetişimi ve akıllı ajanda vizyonunun kentsel sürdürülebilirlik ile uyumlu olup olmadığı açısından çok önemli görünmektedir.

Ayrıca, dinamik faktör analizi kullanılarak 2005-2019 dönemi için seçilen 33 ilin statik ve dinamik bir sıralaması sağlanmaktadır. Bu karşılaştırmalı çalışmada, en iyi (ve en kötü) akıllı şehri belirlemek ve akıllılıkta son 15 yılda meydana gelen değişiklikleri vurgulamak için şehirler teknoloji, topluluk,

altyapı, topluluk ve yönetişim dahil olmak üzere çeşitli akıllı etmenlere göre değerlendiriliyor ve sıralanıyor. Bu analizin sonuçları, şehirlerin belirli güçlü ve zayıf yönlerini belirlemek için ampirik bir temel ve akıllı şehirlerin büyümesini ve performansını iyileştirebilecek politikaların seçilmesinde politika yapıcılar ve metropol liderleri için bilgiye dayalı bir karar verme aracı olarak hizmet edebilir.

Bu araştırmanın bulguları, belirlenen sinerjilere kıyasla akıllı şehir göstergeleri ağında yalnızca birkaç takasın olduğunu ortaya koymaktadır. Ayrıca ağ istatistikleri, yenilikçiliğin, iş dünyasının gelişmişliğinin, BİT altyapısının ve hükümet etkinliğinin akıllı bir şehrin temel itici güçleri olduğunu gösteriyor. Ek olarak, bulgular, akıllı şehir girişimlerinin ekonomik sürdürülebilirliği geliştirirken çevresel ve sosyal sürdürülebilirliği tehlikeye attığını göstermektedir. Bu, kentsel sistemlerin karmaşıklığını ve sürdürülebilirlik zorluklarını ele almak için koordineli bir yaklaşıma duyulan ihtiyaca işaret ediyor. Son olarak, araştırma, politika yapıcıların ve özel ve kamu sektörlerinin çabalarını akıllı şehir girişimlerinin daha etkili ve verimli stratejik planlamasına ve uygulamasına yönlendirmek için birkaç öneri önermektedir.

**Anahtar Kelimeler:** Akıllı şehir; kentsel gelişim; akıllı politika; kentsel sürdürülebilirlik, sıralama, yönetişim; sıralama, göstergeler, şebeke analizi; dinamik faktör analizi; PVAR.

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# ABBREVIATIONS

**AHP** : Analytical Hierarchy Process
**ASCIMER** : Assessing Smart City Initiatives for the Mediterranean Region
**CoO** : Cities of Opportunity
**GDP** : Gross Domestic Product
**GMM** : Generalized Method of Moments
**GNP** : Gross National Product
**ICT** : Information Communication Technology
**IISD** : International Institute for Sustainable Development
**MDGs** : Millennium Development Goals
**OECD** : Organisation for Economic Co-operation and Development
**PVAR** : Panel Vector Autoregression
**R&D** : Research and Development
**RFID** : Radio-frequency Identification
**SC** : Smart City
**SCMM** : Smart City Maturity Model
**SDGs** : Sustainable Development Goals
**TFP** : Total factor productivity
**UN** : United Nations
**UNDP** : United Nations Development Programme
**WCED** : World Commission on Environment and Development

# INTRODUCTION

Cities are the most important factor influencing the social and economic development of countries, as the UN predicted that 70% of the world's population will live in cities by 2050. In addition, 75% of the world's energy resources and 80% of emissions are consumed or produced in cities. These trends place enormous strain on urban systems and compound long-standing significant challenges, such as persistent traffic congestion, resource depletion, biodiversity loss, climate change, imprudent land use, air and water pollution, ageing infrastructure, social inequalities, inadequate and ineffective health care, and declining public safety, to name a few.

Faced with increasing pressure to make cities more efficient, governments worldwide have set ambitious emissions reduction targets to drive urban sustainability. In addition, scholars from different disciplines, urban policymakers and planners are working together to explore and implement alternative models and innovative approaches to urban planning and development, recognising the urgent need to move from traditional models to sophisticated practices and solutions, such as integrating ICT into urban systems. As a result, the smart city, as a combination of technology-based solutions and creative approaches to urban planning, has come to the fore as a panacea for improving quality of life and promoting urban sustainability by employing ICT to monitor and connect its infrastructure, optimising the use of resources, improving collaboration between city stakeholders, and enabling the public and private sectors to develop innovative business models.

The smart city concept has rapidly gained prominence in industrial policy discourses on urban development as the leading driver of urban sustainability, coupled with substantial private and public investments in technology development and deployment. Hundreds of smart worldwide are currently devoting enormous resources to these initiatives. And recently, smart cities managed to mitigate some of the negative externalities of the COVID-19 economy by enabling governments, businesses, and communities to cope with the deepening economic recession and to create new solutions through remote work, online education, online-based entertainment, and online shopping.

Complex relationships between a city’s inhabitants are affected by both tangible (transport and communications infrastructures) and intangible infrastructures

(economic and human capital), generating tangible or intangible networks. This complex system requires a realistic illustration using a network system that can express the interconnection between the various elements. The hallmark of smart cities is their dynamic and multidimensional endowments allowing the integrated governance of complex city systems.

The literature on smart cities has evolved rapidly to focus on the various dimensions of smart cities ranging from smart economy and smart living to the impact of technology on urban ecosystems. However, the smart city literature has yet to lay out a systematic analytical framework that can illustrate how the complex drivers of smart cities interact in a holistic manner through feedback loops and how they relate to smart city outcomes. In other words, the identification and quantification of the dynamic effects of smart city drivers and their potential impacts, as well as the systematic illustration of positive and negative interlinkages between them, have yet to be achieved.

In light of the aforementioned gap in the extant literature, this study redefines the concept of a smart city, develops a systematic approach to smart city analysis through the application of network analysis and introduces the negative externalities of smart city implementation. In specific, the study develops two hypotheses. First, effective governance of complex city systems requires increasing synergies and eliminating trade-offs between the smart city drivers and outcomes. Second, this elimination requires classifying the key indicators of smart cities and ascertaining the feedback loops between them. Accordingly, this study introduces a preliminary analytical framework to comprehensively conceptualise smart cities' drivers and potential outcomes, including their negative externalities. The relationships between indicators (synergies and trade-offs) were identified through an extensive literature review, and the identified interlinkages were then quantified and assigned as edge weights by utilising correlation analysis of the indicator-level data for the selected smart cities. The key indicators, which play dominant roles in the network, were identified using four centrality metrics, namely degree centrality, eigenvector centrality, betweenness centrality, and closeness centrality, based on network analysis. Identifying such central dimensions in a smart city network is anticipated to inform policymakers on prioritising smart city policies and strategies. Furthermore, this

study developed an updated smart city framework based on community detection, enabling policymakers to target specific indicators effectively and efficiently.

As the number of smart city projects continues to grow, there is also a notable boom in developing and implementing tools and indicators to assess their performance. The ranking was developed to support investors' investment decisions on the one hand and to guide cities in developing their strategies according to their strengths and weaknesses in order to foster their development and build a competitive position on the other.

While smart city rankings have received much attention in recent years, studies have focused on measuring outcomes influenced by many other aspects rather than smartness itself. In this respect, the smart city concept also includes socio-economic and institutional drivers. Therefore, assessment schemes should cover multiple influencing drivers rather than focusing only on technological indicators. In doing so, a comprehensive coverage of indicators enables a systems-based approach that captures the transformation of urban systems.

Moreover, existing smart city ranking tools focus on a single time period, thus providing a snapshot in time and ignoring the development patterns of cities. Indeed, cities are not static, with many socio-economic and environmental mechanisms constantly changing their underlying dynamics. Accordingly, the assessment and ranking of smart cities should track these changes to understand their performance evolution and progress towards achieving their goals.

This knowledge-based instrument is essential for urban planners and policymakers to assess how smart initiatives impact urban dynamics, evaluate improvements over time, and adjust their plans as necessary. To fill this gap, this research introduces a static and dynamic ranking of smartness employing the drivers of smart cities for 33 selected cities from 2005-2019 using dynamic factor analysis.

A contemporary understanding of *"going smart"* involves the inclusion of dimensions beyond technology that, prima facie, can solve urban challenges. However, urban scholars have been critically vocal about whether smart cities can deliver on their promise of creating urban sustainability, as there is little evidence in practice that smart city initiatives incorporate or achieve sustainability. In fact, smart cities have been criticised for reflecting techno-utopian, neoliberal approaches to

urban development, granting corporate control over cities and pursuing outdated growth agendas.

Indeed, the outbreak of COVID-19 has disrupted the natural rhythm of cities, exposed the weaknesses of urban health infrastructures, and exacerbated the underlying economic and social problems of cities. More than ever, cities need a holistic approach to manage their new realities and deal with these entanglements. Many authors argue that ineffective governance arrangements are the biggest obstacle in transforming cities into smart cities. Indeed, technological developments around the world impact cities regardless of whether they pursue a smart agenda, e.g., by investing in smart city projects.

There is no question that the governance of cities is extremely complex, as different stakeholders, such as citizens, local authorities, and urban planners, often have conflicting interests. In view of that, an appropriate governance system for the multi-layered ecosystems of the smart city is necessary to make proper decisions and facilitate stakeholder linkages and knowledge transfer to achieve the goals of the smart agenda and improve environmental and socio-economic performance. Therefore, identifying the drivers of smart cities and governing them systemically could be of great value.

As mentioned earlier, while much of the research on smart cities focuses on technological aspects, interpreting the concept, creating assessment indices, and highlighting smart city dimensions and performance indicators, it still lacks an integrated and systematic analysis of the phenomenon, which is the root cause of the limited understanding of the interactions between technology and social structure and environment. In particular, the relationship between the drivers of the smart city and its potential contribution to sustainability has been neglected.

Furthermore, empirical research focusing on the governance of the smart city and policies is sparse compared to the large number of ongoing smart city projects worldwide and comprehensive frameworks determining governance mechanisms and how they should be managed are yet to be achieved. This is compounded by ambiguities and misconceptions in the use of smart city outcomes and drivers and in the application of appropriate measurement techniques, which contributes to the limited use of quantitative techniques in smart city analysis. In specific, the

relationship between urban smartness and sustainability changes over time and may not be linear.

Previous studies have neglected the dynamic impact of smart city drivers and only considered the environmental dimension of urban sustainability rather than providing an integrated conceptualisation of sustainability. Therefore, there is an urgent need to close the gap in empirical studies and methodological issues. Against this backdrop, this study takes a holistic perspective and considers the smart city as the interplay of multiple drivers ranging from technology, innovation, governance (exchange arrangements, legislation, and policy) to city stakeholders (with different roles and responsibilities) to achieve long-term goals or functional changes, including sustainability, which is the focus of this research. In specific, the study explores the causal relationship between smart city drivers and their likely impact on sustainability, which remains largely vague in the literature.

Drawing on Boyer's (2006) institutional complementarity hypothesis, the study aims to contribute to the ongoing debate on whether smart cities can achieve sustainability. Specifically, the study provides a rigorous empirical analysis of the systemic governance of smart complementarities and their dynamics using panel data from 26 smart cities from 2009-2019. A city's smartness is measured by four drivers identified based on an extensive literature review. Sustainable urban development is determined on the basis of economic, environmental, and social dimensions. Such an analysis appears to be crucial for the governance of smart cities and whether the vision of a smart agenda contributes to urban sustainability.

The organisation of the thesis follows a logical structure to enable the reader to gain insight and understanding of how the key research objectives have been achieved. Chapter 1 begins by introducing the smart city concept, identifying its key drivers, potential outcomes, and negative externalities. In addition, it discusses the synergies and trade-offs between the smart city drivers and outcomes and introduces a conceptual framework for mapping the interlinkages among the smart city indicators. The latter half of Chapter 1 transitions to a focus on smart city ranking schemes and puts forward a framework for developing a static and dynamic smart city index.

Chapter 2 presents a comprehensive review of the concept of sustainable development and provides an overview of the interlinkages between the sustainability

pillars, the SDGs and urban sustainability. Following this is an extensive discussion of the tensions between smart and sustainable cities. Chapter 2 then transitions to introducing systemic governance and institutional complementarities and operationalising these concepts within the concept of smart cities. Chapter 2 concludes by introducing a conceptual framework for investigating the impact of smart cities on urban sustainability.

Having conceptualised smart cities and urban sustainability in Chapters 1 and 2, Chapter 3 shifts the focus of the dissertation towards the research objectives and questions, describes the sample chosen for the study and discusses the research methodologies used to investigate the research objectives empirically.

Chapter 4 presents the findings and discusses the results of the proposed empirical frameworks. Finally, Chapter 5 concludes by offering policy recommendations and provides a synthesis of important conclusions from this research. The first part of the chapter addresses a number of fundamental questions. These focus on the synergies and trade-offs of the smart city drivers and its outcomes, the impact of smart cities on urban sustainability and the development of smart cities over the past 15 years. An executive summary of unique contributions, limitations and future work follows this section.

Finally, this work has served as a foundation for the development of three impactful papers in the field of smart city research. The first paper delves into the intricate interlinkages between smart city drivers, outcomes, and the potential negative externalities they may generate. It provides a comprehensive analysis of the various factors that drive smart city initiatives and their corresponding impacts, shedding light on the potential trade-offs and unintended consequences that need to be considered in the pursuit of urban technological advancement. The second paper focuses on the evolving landscape of smart city rankings, highlighting the changes observed over the past 15 years. By examining the shifts in rankings, this paper offers valuable insights into the dynamic nature of smart city development and the emerging leaders in this field. Lastly, the third paper investigates the profound impact of smart cities on urban sustainability and proposes a novel framework for effective smart city governance to address sustainability challenges. Together, these three papers advance the understanding of the complex dynamics and implications of smart city

initiatives, paving the way for more informed decision-making and effective urban planning.

# CHAPTER ONE
# THE CONCEPT OF SMART CITIES

## 1.1. Definitions

The concept of the smart city originally evolved from the smart-growth movement in the late 1990s (Bollier, 1998), which proposed a planning approach to address the challenges of urban sprawl, ageing infrastructure, traffic congestion, environmental degradation, and multi-faceted socio-economic problems (Perveen et al., 2019; Rodriguez-Bolivar, 2015; Downs, 2005). Although the term smart city has its roots in urban sustainability, it has become a term for any form of technological innovation in urban planning, development, and management (Yigitcanlar et al., 2019). In fact, the 21st century has seen a shift towards smart city goals instead of sustainability targets (Marsal-Llacuna et al., 2015). In specific, the smart city concept goes back to and complements earlier paradigms, such as digital city, virtual city, ubiquitous city, intelligent city, creative city, knowledge city, hybrid city, information city, and wired city (Albino et al., 2015; Manville et al., 2014; Nam and Pardo, 2011; de Jong et al., 2015; Zygiaris, 2012; Murgante and Borruso, 2015).

Despite the lack of a universally recognised definition of a smart city, its core components can be identified utilising the available definitions, a brief summary of which is presented in Table 1 (Chourabi et al., 2012; Hollands, 2008; Lombardi et al., 2012; Nam and Pardo, 2011). Several perspectives are commonly used to define smart cities, highlighting different aspects of smart cities, and reflecting the different goals and priorities of urban stakeholders. The technological perspective emphasises the role of technological solutions and ICT infrastructures in solving urban issues (Townsend, 2013). The economic perspective underlines the importance of innovation and technology development in promoting urban growth and competitiveness (Zygiaris, 2013). From a social perspective, smart city prioritises citizen engagement, participation, and empowerment in designing and implementing smart city solutions to improve socio-economic equity (Lim and Liu, 2010; Kourtit and Nijkamp, 2012).

The environmental perspective asserts that smart cities use high-tech environmental solutions in combination with traditional green interventions, such as

green spaces to achieve zero or low carbon emissions (Wachsmuth and Angelo, 2018; Kim, 2018). The human-centred perspective recognises the role of active citizen participation and their ability to shape the institutional framework that governs urban development, rather than being passive recipients of services within the *"institutional environment"* (Joss et al., 2017; Cardullo and Kitchin, 2019). The organisational view features the importance of transparent and democratic governance and the digitalisation of government data in creating sustainable and inclusive urban environments (Hollands, 2015; Wang and Deng, 2022).

An investigation of the definitions of the smart city shows that Odendaal (2003), Griffinger et al. (2007), and Nam and Pardo (2011) place a narrow focus on technology without considering the broader social, economic, and environmental factors that shape urban development, while Harrison et al. (2010) and Kourtit and Nijkamp (2012) do not address the governance structures and processes required for effective smart city policy development and implementation. Other definitions, such as that of Harrison et al. (2010), are too broad and lack the specificity needed to guide policy development and implementation. Indeed, the concept of the smart city has undergone a remarkable transformation in recent years, featuring the role of institutions, human capital, the innovative economy, etc., rather than focusing solely on digitalisation as in the definitions of Caragliu et al. (2011), Kitchin (2014), Dameri (2013), and Azevedo Guedes et al. (2018). Though being a core component of the smart city, digitalisation does not suffice to define the scope of the smart city per se, rather smart city is an interdisciplinary field and an evolving concept driven by both technological progress and urban development in a mutually-enhancing manner. Despite this orderly development, the available definitions still lack a systems approach, which restrains the processual and clear-cut understanding of the smart city concept with its inputs, outputs, and feedback mechanisms.

The smart city represents a hybrid model of urban development that combines several aspects of urban strategies. These strategies all have in common the goal of solving urban challenges and improving the quality of life. Therefore, there may be overlaps in the urban indicators of the different urban development strategies, with each strategy emphasising certain factors without ignoring other essential urban indicators, e.g., hard and soft infrastructure. However, comparing smart city initiatives with other urban strategies remarkably brings out two core elements. The first is urban

development based on the technology-driven knowledge economy, and the second is public sector development related to quality governance with ICT-driven business practises and cross-sector innovation (Goodspeed, 2014). More specifically, a smart city combines the processes of digitalisation, urban planning and the various dimensions of urban governance and dynamics. If these dynamics are not taken into account, there is a risk that the policy will fail. Smart city governance is thus based on organising the dynamics within a systemic framework that creates synergies and trade-offs between smart city drivers.

Accordingly, this study defines the smart city as an ICT-driven urban development strategy to achieve urban efficiency, environmental sustainability, public health and safety, government transparency, economic productivity and labour market flexibility through technology, physical infrastructure, community, innovative economy, and governance mechanism by systemically managing and coordinating the complex and multidimensional links between the drivers and the outcomes. The peculiarity of this definition lies in presenting an ordered and processual approach that views smart cities as a system in which its drivers as inputs are transformed into desired outcomes as outputs through the implementation of smart city policies. In so doing, it clarifies the smart city concept by clearly describing the drivers of smart cities, the outcomes of smart cities, the role of smart city policy in utilising the drivers to achieve the outcomes, and the role of ICT in enabling smart city actors to conduct smart city policy in cognisance of all complex and multidimensional relationships between drivers, policies, outcomes, and the feedback loops.

In the context of the analysis, drivers refer to smart city policy instruments, i.e., specific tools and measures used to implement smart city policies. These include regulatory instruments (e.g., building codes and land use policies), financial instruments (e.g. tax incentives, subsidies), ICT instruments (e.g. implementation of Big Data analytics, AI and cloud computing), social instruments (e.g. public awareness campaigns and capacity building initiatives), institutional and governance instruments (e.g. public-private partnerships, dedicated smart city agencies). After a detailed analysis of the smart city literature, the study identifies a set of five drivers as the building blocks of a smart city: Technology, Infrastructure, Community, Governance, and Innovative Economy. These drivers are built on the elements of traditional and neoclassical theories of urban growth and development, i.e., human

and social capital, ICT economics, natural resources, competitiveness, and citizens' participation (Albino et al., 2015; Lombardi et al., 2012). These drivers encompass several indicators and numerous interactions that can drive the outcome of smart cities. Outcomes here refer to the desired changes or impacts that are expected to occur as a result of the implementation of a smart city policy and that are aligned with the policy's objectives. These outcomes include improved urban efficiency, environmental sustainability, public health and safety, government transparency, economic productivity, and flexibility in the labour market.

The proposed definition assumes that the outcomes of a smart city can only be realised if it is driven by smart city policies. In this context, smart city policy is an urban development policy that plays a critical role in shaping the drivers and outcomes of the smart city. It refers to the strategic agenda that aims to develop smart cities by bringing together multiple stakeholders, engaging citizens in the design and implementation of smart city initiatives, and steering investments in ICT and smart public services to transform cities into more efficient, sustainable, and liveable places (Angelidou, 2014; Caragliu and Del Bo, 2019; Tranos and Drew Gertner, 2012). Smart city policies should ensure that the interlinkages between the drivers of smart cities are managed effectively and that the risks and challenges associated with the presence of conflicting goals are addressed.

**Table 0.1:** Selected definitions of the smart city, sorted by year of publication.

| Definition | Author | Focus |
|---|---|---|
| "A city that capitalises on the opportunities presented by ICTs in promoting its prosperity and influence." | Odendaal (2003) | Technology |
| "The use of smart computing technologies to make the critical infrastructure components and service of a city—which include city administration, education, health care, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient." | Washburn et al. (2009) | Technology |
| "Smart cities combine ICT and Web 2.0 technology with other organisational, design, and planning efforts to de-materialize and speed up bureaucratic processes and help identify innovative solutions to city management complexity to improve sustainability and "liveability." | Toppeta (2010) | Technology, Innovation, Quality of life |
| "A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city." | Harrison et al. (2010) | Technology, Physical, natural, social infrastructure Businesses |
| "A city that is smart when investments in human and social capital and traditional transport and modern ICT infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." | Caragliu et al. (2011) | Technology, Physical, soft and natural infrastructure, Governance, Quality of life |
| "A smart city is ICT-enabled public sector innovation made in urban settings. It supports longstanding practices for improving the operational and managerial efficiency and the quality of life by building on advances in ICTs and infrastructures." | Nam and Pardo (2011) | Technology Quality of life |
| "Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socioeconomic, ecological, logistic, and competitive performance of cities. Such smart cities are based on a promising mix of human capital, infrastructural capital, social capital and entrepreneurial capital." | Kourtit and Nijkamp (2012) | Soft infrastructure Technology Entrepreneurship Sustainability |

| | | |
|---|---|---|
| “A smart city is a well-defined geographical area, in which high technologies, such as ICT, logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well-being, inclusion and participation, environmental quality, intelligent development; it is governed by a well-defined pool of subjects, able to state the rules and policy for the city government and development.” | Dameri (2013) | Technology Quality of life Sustainability Governance |
| "Smart cities' is a term to describe cities that, on the one hand, are increasingly composed of and monitored by pervasive and ubiquitous computing and, on the other, whose economy and governance is being driven by innovation, creativity, and entrepreneurship, enacted by smart people." | Kitchin (2014) | Technology, Innovation, Entrepreneurship, Human capital |
| "A coherent urban development strategy developed and managed by city governments seeking to plan and align in the long term the management of the various city's infrastructural assets and municipal services with the sole objective of proving the quality of life for the citizens." | Dustdar et al. (2017) | Quality of life Infrastructure Governance |
| “Smart cities enhance intelligence and sustainability through governance that integrates interactions between stakeholders and technologies that optimise services and infrastructure to improve quality of life.” | Azevedo Guedes et al. (2018) | Technology Infrastructure Governance |

### 1.2. Drivers Of Smart Cities

Several studies examine the factors/drivers that make a city smart (Mohanty et al., 2016; Giffinger and Gudrun, 2010; Chourabi et al., 2012; Nam and Pardo, 2011; Noori et al., 2020; Nicolas et al., 2020; Gil-Garcia et al., 2015; Thompson, 2016; Sujata et al., 2016). Many scholars rightly argue that technology alone cannot create urban smartness; instead, true urban smartness requires smart citizens and proper governance (Morse, 2014). Essentially, the conceptualisation of a smart city can be based on five key drivers, namely technology, Infrastructure, governance, community and innovative economy. These components encompass several indicators and numerous interactions that can drive the outcome of smart cities. These drivers are built on the elements of traditional and neoclassical theories of urban growth and development, i.e., human and social capital, ICT economics, natural resources, competitiveness, and citizens’ participation (Albino et al., 2015; Lombardi et al., 2012).

### 1.2.1. Technology

The first driver, technology, is a cornerstone of smart city initiatives (Chourabi et al., 2012; Rodrigues and Franco, 2021) and evaluates the city's readiness to transform into a smarter one and supply smart services to citizens. Technology extends over the other drivers and helps improve and connect them (Pereira et al., 2017). In view of that, smart cities incorporate infrastructure systems, technologies, and services into a flexible and open-access 'organic network' for socioeconomic development. Thus, technology functions as a facilitator for forming innovative institutions and a collaborative environment (Komninos, 2011).

Technology as the main driver for the smart city initiative consists of two components, namely ICT infrastructure and ICT use. First, the availability of ICT and new technologies, such as the Internet of Things, cloud computing, sensors, fibre optic channels, Wi-Fi networks, and wireless hotspots are enabling the development of smart city initiatives (Rodrigues and Franco, 2021). Noori et al. (2020) explain how smart cities transform real-time data, e.g., from transport, health, environment, and economy, collected via sensors, RFIDs, etc., into reliable information and smart applications that city stakeholders can use. This is measured by the city's ICT infrastructure, including mobile network coverage, international internet bandwidth, and secure internet servers (Giffinger et al., 2010; Al-Hader and Rodzi, 2009; Lee et al., 2014; Smiciklas et al., 2017). Other indicators of a city's readiness for digital infrastructure include the quality and performance of ICT infrastructure, which influences smart city performance (Government Summit, 2015), the affordability of broadband networks and the security and privacy of stakeholder data (Nicolas et al., 2020).

Second, while ICT infrastructure is a prerequisite for a smart city, the commitment and willingness of stakeholders to adopt digital tools are crucial for successful implementation. In other words, smart technologies are based on their usability by citizens and other stakeholders in the city (Masik et al., 2021). Indeed, ICT use reflects the community's transition into an innovative society capable of adopting new technologies and applications, e.g., e-government, e-commerce, e-books, and creating innovative solutions to persistent urban challenges. Both internet use and mobile broadband subscriptions indicate citizens' access to information and

technological connectivity and the state of technological development of connectivity in a city. Higher penetration rates indicate better access to communication, technology for information sharing, knowledge about technology trends, and higher digital inclusion. In addition, Wi-Fi hotspots in public areas promote e-services and allow citizens to access the internet at a low cost.

### 1.2.2. Infrastructure

The second driver, physical infrastructure, is necessary to integrate transportation modes with the use of ICT to create innovative, sustainable, safe, and balanced transportation systems, such as subways, monorails, and 'SkyTrain' for high-speed travel. It also includes effective management of natural resources and capitalising on innovative technologies, such as renewable power resources and solar energy to enhance the city's sustainability, and quality of life.

Reliable physical infrastructure is needed to leverage available technologies, which includes an efficient transport system that provides improved transport networks for citizens and goods. This is measured by the quality of the transport infrastructure (Bosch et al., 2017). Overall, digitalisation and the integration of technologies into transport systems optimise the urban transport system's cost, time, safety, efficiency, and reliability. In addition, wiser management of natural resources is another important indicator for smart city initiatives (Antrobus, 2011).

Towards this end, smart cities employ technological innovations, including smart energy systems, which aim to reduce energy consumption by reusing and substituting resources, and efficient management systems for the disposal and treatment of municipal, industrial, and hazardous wastes (Noori et al., 2020; Kumar and Dahiya, 2017). The energy systems, water resources, and waste management systems (Mega and Pedersen, 1998; Li et al., 2015) constitute an interrelated and complex network in the city, which requires a comprehensive understanding of each system and its interaction with the others to improve its function (Dirks et al., 2009).

### 1.2.3. Community

The third driver, the community, is driven by human and social capital and involves several factors, such as participation, digital proficiency, and lifelong

learning. Smart communities are highly flexible and resilient to changing environments and creative and innovative in overcoming challenges, in addition to their active involvement in the city's sustainable development (Kumar and Dahiya, 2017). Many researchers argue that smart cities should start with human and social capital rather than relying on technology alone to solve urban challenges (Shapiro, 2006; Holland, 2008; Toppeta, 2010).

ICT creates a novel communicative environment that requires matched development of digital and creative skills (Komninos, 2011). Hence, the success of smart city initiatives depends on the participation of citizens in urban life by developing creative solutions, adapting to the digital and innovative environment, and engaging in the community. Therefore, education, training, and citizen engagement in smart city projects, i.e., living labs, workshops, etc., as indicators of the workers' and citizens' future capacity, are the most important means of developing smart initiatives (Dvir and Pasher, 2004; Smiciklas et al., 2017).

Another important driver of smart cities is the ability of their communities to adopt ICT in their urban lives to share, produce, and benefit from data within the city to develop innovative and intelligent solutions (Nam and Pardo, 2011; Cardullo and Kitchin, 2019). Thus, citizens' digital proficiency strengthens human capital, which in turn is a target for smart cities to leverage the smart brand (Noori et al., 2020). Finally, creativity in the fields of arts, technology, and culture is a key driver of the knowledge economy and urban development and an essential feature for attracting smarter people to the city and thus becoming a smarter city (Sasaki, 2007; Myeong et al., 2018).

### 1.2.4. Innovative Economy

The economy is a major driver for smart city initiatives. An innovative economy, leverages innovation and technology, creates collaborations among institutions, businesses, citizens, and research entities, and uses existing or renewable resources to develop new models of consumption, production, and distribution (Bakici et al., 2013; Zygiaris, 2013; Anttiroiko, 2013). The economy of a smart city advocates green growth, generates high added value, creates a favourable environment for business, increases efficiency, and overcomes economic challenges based on competitiveness, entrepreneurship, openness, labour market flexibility,

intellectual property, and environmental and social responsibility (Chourabi et al., 2012).

There are four components that underlie the innovative economy. First, an R&D budget is essential to foster innovation and the development of new smart applications (Hoppe et al., 2016; Bosch et al., 2017). Second, entrepreneurship is a vital indicator of an innovative economy, which catalyses creativity and innovation. The number of newly registered businesses in a city indicates the level of entrepreneurial activity, job creation, competition in both the local and global economy, and innovation (Lombardi et al., 2012; ITU, 2017).

Third, as smart city projects rely on ICT, the employment rate in knowledge-intensive sectors is an important indicator of an innovation-driven economic structure (Mhangara et al., 2016; Huovila et al.,2019; Schiavone et al., 2019). Finally, business sophistication reflects the tendency of the private sector to take risks, implement new ideas and create cutting-edge products and services, which are essential for the smart city initiative (Zygiaris, 2013; Bakıcı et al., 2013).

### 1.2.5. Governance

The fifth driver, governance, is fundamental to smart city initiatives. It means the development of ICT-mediated administration to provide efficient public services to citizens through electronic channels, i.e., e-government, crowdsourcing, and social media (Paskaleva, 2009). It stands for collaboration and cooperation among stakeholders, including local governments and non-governmental organisations, in transparent decision-making processes and public services (Giffinger and Gudrun, 2010). The spirit of e-governance in a smart city is citizen-centric, and citizens participate in policymaking, planning implementation, and monitoring. A smart city uses big data, geospatial technologies, and the triple helix model (interplay between government, industry, and academia) for city governance and socioeconomic development.

Governance can be defined as the processes designed to ensure the transformation of a city into a smart city, including monitoring the city's different domains (Hoppe et al., 2016; Bressers et al., 2016). It is important to distinguish between smart city transformation governance (driver), which involves the design and

implementation of smart city policies, and smart governance (outcome), which means the integration of ICTs into government services to increase government transparency and accountability. Government readiness entails removing legal and regulatory barriers to facilitate the implementation of smart city initiatives (Chourabi et al., 2012). This includes laws that protect and secure data sharing for all city stakeholders (Maccani et al., 2013).

Governing smart cities is based on integrating technology into the traditional mode of governance and collaborating with city stakeholders to improve public institutions and services. It requires active participation in decision-making, public and social services, administrative effectiveness, and the use of e-government (Gil-Garcia and Pardo, 2005; Smiciklas et al., 2017; Manville et al., 2014). Another noteworthy factor for successful smart city implementation is citizens' involvement and participation in decision-making, which serves as a catalyst for inclusive urban growth (Odendaal, 2003; Gil-García et al., 2015). This is measured by the Civil Society Participation Index, which assesses society engagement, participatory environment, consultation, and engagement in political and non-political associations.

As mentioned earlier, smart governance results from the bidirectional flow of information and services between the government and citizens, improving the administration's ability to find solutions to the citizens' challenges. One example is e-government which increases the efficiency and accessibility of public services through the internet and electronic services (Tanda et al., 2017; Garcia-Fuentes et al., 2017; Smiciklas et al., 2017).

The efficiency achieved by the city government is an important factor in governing smart initiatives, which ensures the quality of public and civil services, the quality of policies and the credibility of the government, and its independence from political pressure (Nam and Pardo, 2011). Both OECD countries and the United Nations General Assembly recognise the role of e-government in improving public policies and the quality of services and promoting government efficiency. The latter is important because in many scenarios, different agendas, such as a green agenda and brown agenda, can lead to conflicting goals, especially in the presence of political competition or budget constraints where 'power dynamics' determine support for one

agenda over another, resulting in potential benefits not being fully realised (Bai et al., 2018).

In light of the above, the concept of smart cities can be understood as an interplay of policies for hard infrastructure (ICT, built environment) and soft infrastructure (human and social capital, innovation, quality of governance). Achieving an optimum outcome for smart cities requires that these complex, multidimensional, and interconnected drivers work in a synergistic fashion. Table 1.2 summarises the key drivers of the smart city.

**Table 0.2:** The list of SC drivers in this study.

| Driver | | Reference |
|---|---|---|
| | **TECHNOLOGY** | |
| ICT Infrastructure | -Technology is a crucial enabler (mean) for developing smart cities. | Zygiaris (2013); Nam and Pardo (2011); Neirotti et al. (2014); Albino et al. (2015); Simonofski et al. (2017); Silva et al. (2018), Joss et al. (2019), Kitchin (2014); Eger, (2009) |
| ICT usage | -The commitment and willingness of stakeholders to adopt the digital tools are crucial for successful smart city implementation. | Masik et al. (2021) |
| | **INNOVATIVE ECONOMY** | |
| Innovation (total R&D expenditure) | -A smart city policy develops the urban innovation process by generally improving local knowledge and production functions (Caragliu et al., 2019). Innovation develops markets | Albino et al. (2015) Simonofski et al. (2017) Silva et al. (2018) |

| | | |
|---|---|---|
| | for new products, focuses on higher value-added activities, and expands supply chains, enhancing the local competitive advantage. | |
| Entrepreneurship | -Entrepreneurs initiate technological interventions, i.e., developing new technologies and collecting data to define new opportunities that help cities undergo a socio-technical transformation and become smart cities. | Yigitcanlar (2018)<br>Kummitha (2019)<br>Richter et al. (2015) |
| High-tech Industry Employment in ICT | -As the smart city's infrastructure is based on ICT, the ICT sector must have the necessary workforce to drive research and enable advances in digital technologies. | Griffinger et al. (2007) |
| Innovation & sophistication factors | -Business sophistication, capacity for innovation, university-industry collaboration in R&D, government procurement of advanced technology products, availability of scientists and engineers, patent applications, and intellectual property protection are all important for developing smart cities. | Albino et al. (2015)<br>Simonofski et al. (2017)<br>Silva et al. (2018) |
| | **COMMUNITY** | |
| Education | -Smart city initiatives involve human capital investments that aim to improve a city's capacity for learning and innovation by supporting and motivating locals in education and attracting and retaining valuable inputs (highly skilled individuals) from abroad. | Glaeser and Berry (2005)<br>Hollands (2008)<br>Gil-Garcia et al. (2015)<br>Zygiaris (2013)<br>Nam and Pardo (2011)<br>Neirotti et al. (2014) |

| | | |
|---|---|---|
| Digital Proficiency | - Digital skills are vital to transforming innovative digital technologies into applications. | Zygiaris (2013)<br>Neirotti et al. (2014)<br>Albino et al. (2015)<br>Simonofski et al. (2017)<br>Silva et al. (2018)<br>Noori et al. (2020)<br>Komninos (2008) |
| Creativity | -The main driver of the new knowledge economy is 'creativity,' especially artistic and technological creativity that deals in creative assets in the form of intellectual property, in which creativity is translated into economic value. | Zygiaris (2013)<br>Nam and Pardo (2011)<br>Neirotti et al. (2014)<br>Gil-Garcia et al. (2016) |
| | **NATURAL & PHYSICAL INFRASTRUCTURE** | |
| Quality of Transport Infrastructure | - Efficient transport is the cornerstone of the smart city initiative, which aims to integrate ICT into existing urban infrastructure. | Bosch et al. (2017) |
| Renewable energy consumption | -Since cities are the main sources of global energy consumption. Smart cities entail renovation and innovation of energy generation, energy-efficient buildings, and transport systems crucial to the transition to a sustainable environment. | Monzon (2015) |
| Patents in environment-related technologies | -Smart cities utilise technology to improve essential aspects of urban life, such as waste disposal, pollution control, smart power grids, and smart buildings. | Appio et al. (2019) |
| Municipal waste treated | -Smart waste management systems convert waste into resources to create a circular economy. | UNCTAD (2016) |

| GOVERNANCE | | |
|---|---|---|
| Government effectiveness | -An important aspect of smart cities is using government data and information. Regarding government effectiveness, data supports decision-making and improves everyday situations. Thus, the role of institutional arrangements is central when selecting, adopting, designing, implementing, and using ICT. | Joss et al. (2019) Gil-Garcia et al. (2015) Pereira et al. (2017) Cordella and Iannacci (2010) Luna-Reyes et al. (2008) |
| Digital Governance | -E-government integrates workflows and processes, manages data and information effectively, improve public service delivery, and expand communication channels for engaging and empowering citizens through the development of ICT. | Akman et al. (2005); Gil-Garcia et al. (2014). |
| E-Participation Index | - Smart technologies should be implemented in parallel with improved usability for citizens and their participation. | Simonofski et al. (2017) Joshi et al. (2016) |
| Civil society participation | -Active involvement and collaboration among stakeholders are key for smart city initiatives. | Caragliu et al. (2011) Klimovsky et al. (2016) |

### 1.3. Smart City Outcomes

The impact that smart city drivers can exert on urban performance has yet to be fully explored, and studies merely list indicators arbitrarily without understanding these drivers' dynamic direct and indirect effects on potential outcomes. For instance, digitalisation can directly improve the quality of life (Hall et al., 2000; Dameri, 2017; Braun et al., 2018), and it can also indirectly boost urban space by enhancing government services (Nicolas et al., 2020). That is, the outcome of the smart city

initiative is the impact of the implementation of the smart city policy in which the drivers are deployed. In this context, greater utilisation of smart services yields more significant outcomes.

### 1.3.1. Potential Outcomes

The core of smart cities is the use of technology to address urban challenges by improving flexibility, accessibility, and sustainability and by providing innovative solutions through the integration of ICT in public spaces and facilities, as well as through the provision of a range of applications and services that improve the quality of life through an 'ICT-enabled' lifestyle, i.e., smart sensors, 5G, surveillance systems, e-health, smart home, etc. (Petrova-Antonova and Ilieva, 2018; Mulligan, 2010). Consequently, an increase in urban intelligence is considered to have the following positive outcomes.

#### 1.3.1.1. Urban efficiency

A smart city aims to efficaciously manage traffic congestion, save costs and time, reduce carbon emissions by optimising technologies and provide access to local and international transportation (Angoso, 2009; Alshahadeh and Marsap, 2018). By collecting data and sharing information with planners, transportation managers, and users, the integration and coordination of transportation modes are improved, revolutionising urban mobility patterns. Innovative transportation systems, such as electric vehicles and other alternatives, including bicycles and car sharing, help reduce air pollution and traffic congestion. Smart cities seek to provide bike lanes, smart parking, and public charging stations for electric vehicles to encourage clean 'alternative' transportation (Shields et al., 2009; Garcia-Fuentes et al., 2017). Further, intelligent transportation systems are interconnected through various communication and navigation systems that provide citizens with information related to traffic, available modes, alternative routes, etc., along with innovative traffic monitoring systems so that traffic flow, safety, and security of passengers are improved (Silva et al., 2018; Petrova-Antonova and Ilieva, 2018). This can be measured by the Traffic index, an index of time spent in transport, dissatisfaction due to long commute times, transport-related $CO_2$ consumption, and overall inefficiency of the transport system (Priano and Guerra, 2014; Smiciklas et al., 2017).

#### 1.3.1.2. Environmental sustainability

Smart city initiatives seek to transform a city into a green and sustainable city (Odendaal, 2003). On the whole, the environmental element of a smart city can be divided into environmental sustainability, which aims to preserve the city's natural resources and monitoring systems, which assess and evaluate the city's natural environment (Gil-Garcia et al., 2015). Smart projects introduce technologies that can be utilised to measure energy and resource consumption and ration consumption among individuals and businesses by raising awareness of the environment and modifying consumption behaviour (Monzon, 2015). Various indicators measure pollution in the city, such as the pollution index, which indicates the total pollution of air, water, noise, and light in a city (Gabrys, 2007).

#### 1.3.1.3. Quality of life

Of particular interest to the smart city is the provision of accessible, high-quality healthcare to citizens, which can potentially improve citizens' life expectancy (Bosch et al., 2017; Baucells, 2016; Smiciklas et al., 2017). Urban safety is another outcome that is appraised by the crime rate in the city (Giffinger et al., 2007; Smiciklas et al., 2017;).

#### 1.3.1.4. Economic outcome

The economic outcome of a smart city includes boosting the city's competitiveness based on improvement in productivity, business creation, labour market flexibility, and sustainable economic growth (Huovila et al., 2019; Yeh, 2017; Lombardi et al., 2012). Labour market flexibility can be represented by the employment rate as a signal of both aggregate economic performance and the labour market (Petrova-Antonova and Ilieva, 2018; Kumar and Dahiya, 2014).

#### 1.3.1.5. Government transparency

A chief outcome of smart city initiatives is government transparency, which is assessed through accountability of officials, fighting corruption, and open data (Anand et al., 2017, Mooij, 2003; Nfuka and Rusu, 2010; Giffinger et al., 2007). ICT facilitates citizen interaction with the government, enabling greater participation and more transparent and accountable institutions that strengthen the overall democratic

process (Sujata et al., 2016). Table 1.3 summarises the potential outcomes of the smart city.

**Table 0.3:** The list of smart city potential outcomes.

| Outcome | Channel | Reference |
|---|---|---|
| Productivity | -Integrating technological inputs into new urban development boosts productivity, which is a decisive factor in competitiveness and the level of prosperity a country can achieve. Further, utilising practices and applications of e-commerce and e-business escalate city productivity. | Allam and Newman, (2018)<br>Angelidou (2015)<br>Kraus et al. (2015)<br>Manitiu and Pedrini (2016)<br>Sala-i-Martín (2016) |
| Flexibility in the labour market | -Smart cities increase productivity, competitiveness, and economic growth, enhancing labour market efficiency and flexibility. These are crucial to ensure that workers are allocated most effectively in the economy and are incentivised to bring their best at work. | Allam and Newman (2018)<br>Griffinger et al. (2007) |
| Env. Sustainability | -Smart environmental applications in the energy field; renewable energy, ICT-based energy grids, pollution control, monitoring, green buildings and urban utility networks, such as street lighting and waste management reduce pollution and improve water quality. The Internet of data and the Internet of Things can help reduce the ecological footprint of smart cities. | Appio et al. (2019)<br>Hall et al. (2000)<br>Vasseur and Dunkels (2010) |
| Health | - Accessibility to primary health care and promoting healthy lifestyles are key smart city goals in the health dimension. | Bosch et al. (2017)<br>Baucells et al. (2016) |

| | | |
|---|---|---|
| Safety | -The integration of new ICT platforms can have a significant impact on reducing crime rates and increasing public safety, which improves the well-being of society. | Mendonça et al. (2016) |
| Urban Efficiency | -Smart city projects aim to improve the current state of traffic congestion in urban areas. Real-time information that the public can access saves time and costs, improves commuting efficiency and reduces $CO_2$ emissions. | Appio et al. (2019)<br>Chourabi et al. (2012)<br>Silva et al. (2018) |
| Government transparency | -Open information flows increase transparency and prevent information asymmetries, improving participation. | De Wijs et al. (2016)<br>Fernández-Güell et al. (2016); Mooij (2003)<br>Nfuka and Rusu (2010)<br>Gil-Garcia et al. (2015)<br>Kitchin (2014) |

### 1.3.2. Negative Externalities

While smart cities are the promising future for urban development, growing concerns have emerged vis-à-vis the downsides of their implementation. Available frameworks have overlooked the negative externalities of smart cities and the possible channels that could lead to such an outcome.

Critics of the smart city list a number of disadvantages associated with digitisation and the implementation of smart city projects, including the digital divide, growing income inequality, security and privacy issues, and the restriction of freedoms, to name a few (Perera et al., 2014; Kitchin et al., 2019; Odendaal, 2003; Lam and Ma, 2019; Van Winden and de Carvalho, 2017). First, uneven diffusion of ICT in cities, digital illiteracy, high costs, and resistance to change foster the digital divide (Caragliu and Del Bo, 2022). This, in turn, can exacerbate income inequality in cities as low-income citizens cannot take advantage of available technologies (Belal

and Shcherbina, 2018). Hollands (2015) and Lee et al. (2020) argue that the development of smart cities is driven by profit-oriented companies that offer technical solutions to municipalities instead of improving the well-being of citizens involved in the process.

Recently, many opponents of integrating ICTs into urban infrastructure have voiced concerns about privacy, such as hacking, viruses, invasion of privacy, and theft of personal data (Elmaghraby and Losavio, 2014; Rabari and Storper, 2015). These adverse effects include interruption of business processes, Leakage of confidential data of companies and customers, fiscal or accounting fraud, phishing, identity theft, and mobile banking, as well as disruptions or failures in smart infrastructure systems. Finally, data collection, constant surveillance, and networking of urban systems under central control could affect democracy and freedom of speech (Galdon-Clavell, 2013; Angelidou, 2017, Vanolo, 2016).

Based on the conceptual literature on smart cities and the above indicators, an integrated framework is proposed to explain the relationships and complexities between smart city drivers and outcomes. This framework differentiates the drivers of smart cities and their outcomes and includes, for the first time, the negative externalities which might materialise due to the development of smart cities. These drivers, together with desired outcomes and negative externalities, constitute a smart city framework in which each indicator represents a distinctive feature of the smart city concept. Table 1.4 summarises the list of the negative externalities of smart cities.

**Table 0.4:** The list of negative externalities of smart cities.

| NEGATIVE EXTERNALITIES | | |
|---|---|---|
| Digital divide* | Smart cities can increase inequalities and promote a digital divide when technology is unequally distributed among areas and citizens. | Van Winden and de Carvalho (2017); Bilbil (2017); Caragliu et al. (2011); Klimovsky et al. (2016); Rabari and Storper (2014) |
| Inequality | Citizens unable to take advantage of available technologies lag behind, which widens the income gap. | Jaumotte et al. (2008) Dabla-Norris et al. (2015) |
| Privacy issues** | Smart services are associated with privacy concerns, such as hacking, viruses, invasion of privacy, and theft of personal data. | Chourabi et al. (2012) Galdon-Clavell (2013) |
| Diminishing Freedom/Democracy | Data collection, constant surveillance, and networking of urban systems under central control affect democracy and freedom of speech. | Galdon-Clavell (2013); Angelidou (2017); Vanolo (2016) |

* **Digital divide:** Access to the internet of certain population segments (financial constraints, geographical area, certain ethnic, religious, gender, LGBT+, migrant, pricing practices by service providers).

****Privacy issues:** Does monitoring and collecting user data by service providers and other technology companies infringe on users' privacy rights? - Does state surveillance of internet activities infringe on users' right to privacy?

## 1.4. Synergies And Trade-Offs Between Smart City Drivers And Outcomes

A key question for smart cities today is what role they should play in urban planning to better address urban challenges and growth. Available frameworks and ranking schemes for smart city performance assume that the smart city dimensions and their indicators interact in positive synergy and, therefore, the complex horizontal and vertical interactions described in Figure 1 do not create any trade-offs. In other words, previous research black-boxes the transmission mechanism between policy and outcomes and assumes that "*smartening*" policies will automatically ameliorate urban challenges. These assumptions are not invariably valid (Sharifi, 2019). In addition, while some ranking tools, such as ASCIMER (Assessing Smart City Initiatives for the Mediterranean Region), CoO (Cities of Opportunity)**,** and SCMM (Smart City Maturity Model) assume that smart city indicators are interrelated, no concrete empirical evidence of these linkages has been found yet (Sharifi, 2019).

A crucial point to deepen the understanding of the concept and function of smart cities is the interplay between tangible and intangible components of smart cities. Given this, communities with high human capital tend to have higher labour productivity, which is crucial to urban growth (Combes et al., 2008; Berry and Glaeser, 2005). Human capital accumulation implies positive externalities on social capital through better political engagement, improved social interactions, and lower crime rates (Moretti, 2004). Better educated citizens undoubtedly have high environmental awareness, are willing to purchase greener products or pay for a cleaner environment, and advocate for environment-friendly laws that reduce pollution in the city.

Second, efficient transportation networks and real-time data increase city productivity and improve accessibility. For instance, Duranton and Turner (2012) demonstrated how cities increased employment by 1.5% over the medium term by increasing the stock of highways by 1.5%. Furthermore, integrating ICT into transportation infrastructure improves the quality of life in the city by providing real-time information about traffic, available transport modes, and delays. Furthermore, applying ICT tools in transportation systems enables monitoring and managing these systems, reducing traffic accidents and mitigating environmental problems (Cohen et al., 2002). In addition, environmental technologies facilitate urban economic growth

by reducing natural resource depletion and preserving factors of production for future generations (Camagni and Capello, 2013).

Third, smart governance fosters participation, collaboration among urban stakeholders, and involvement in decision-making regarding smart city strategy, especially among universities and businesses, making cities more efficient and, in turn, less corrupted. In addition, the adoption of e-government promotes public services and improves communication and engagement through three channels: Government to Government (G2G), where government actors at the national, provincial, and local levels exchange and share data; Government to Business (G2B) and Government to Citizen (G2C), which are designed to enable both businesses and citizens to interact with government, regarding business transactions and public services (e-services) and information through government portals (UN, 2003). Nonetheless, democratic and inclusive governance, e.g., data protection and minimal surveillance, is essential in this process, or ICT adoption could drive information inequalities and the digital divide (Nicholas et al., 2020).

Fourth, an innovative economy turns urban problems into investments and profitable opportunities. Investment in smart projects is the source of sustainable employment. Atkinson et al. (2009) found that investing about US$ 30 billion in ICT, energy grid, and health projects can create nearly one million jobs. These projects have significant positive impacts on the environment and quality of life in the city. Furthermore, the emergence of innovative business models, such as e-business and e-commerce enhances the quality of life.

Finally, the diffusion of ICT infrastructure combined with increased technology use supports knowledge-based innovation (Higón, 2012; Xu et al., 2019), increases productivity growth and efficiency, and accelerates entrepreneurship (Lee et al., 2011; Jerome, 2011; Nair et al., 2020). ICTs enable higher educational attainment by engaging communities without access to formal education (Oyerinde and Bankole, 2019) and create new opportunities for individuals to develop their creativity (Ala-Mutka, 2008). In addition, the internet is an effective tool for citizens to engage in socio-political activities through e-participation (Zheng and Schachter, 2017) and for civil society to share its agendas and expand its connections (Sey and Castells, 2004; Haythornthwaite, 2005). Expanding ICT coverage in cities reduces the digital divide

(Rallet and Rochelandet, 2007). Nevertheless, ICT use, increased production, and disposal of e-waste can pose a threat to environmental sustainability (Houghton, 2015).

The above discussion shows that all city systems function like an interconnected network wherein no system can operate in isolation. This means that cities should follow an integrated framework that considers the interrelationships between different systems as viable solutions to long-term challenges.

As mentioned earlier, identifying the complex interlinkages resulting from the interactions between the drivers of smart cities and the outcomes is still absent from the literature concerning smart cities. Therefore, the extensive literature review in this study includes several fields, including, inter alia, environmental economics, macroeconomics, sustainable development, urban development, development economics, and political economy, to trace these complex relationships. Below is a detailed discussion of these interlinkages.

1- ICT infrastructure supports knowledge-based innovation (Higón, 2012; Xu et al., 2019), enhances productivity growth and efficiency, leading to higher employment, especially in the technology sector, and accelerates entrepreneurship (ITU, 2003; Lee et al., 2011; Jerome, 2011; Nair et al., 2020; Kim, 2007). ICT enables higher educational attainment by engaging communities without access to formal education (Ganju et al., 2015; Oyerinde and Bankole, 2019). New technologies, such as the Internet and cell phones provide new opportunities for individuals to develop their creativity (Ala-Mutka, 2008) and enable greater participation in the political process (Weber et al., 2003). In addition, ICT solutions and green technologies, such as renewable energy play a crucial role in improving energy efficiency and reducing greenhouse gas emissions (Chourabi, 2012; Uddin, 2012; Chavan and Chavan, 2019). Nevertheless, ICT use, increased production, and e-waste disposal can pose a threat to environmental sustainability (Houghton, 2015). Real-time data and intelligent transportation systems, such as navigation systems and electronic tags (RFID) improve transportation networks and mobility, reduce $CO_2$ emissions, and save time, costs, and energy (Chourabi et al., 2012; Pešić and Kojić, 2012). In particular, using applications, such as e-banking and e-commerce allows online transactions instead of physical mobility, resulting in less traffic congestion. On the

other hand, ICT applications are used by many sectors, such as healthcare, where ICTs improve treatment, consultation, monitoring, research, awareness of potential risks, and administrative costs (OECD, 2010). Moreover, ICT enables governments to provide information about their administration and functions, as well as online access to their services through e-government and promote citizen participation through e-participation (Kudo, 2008; Srivastava and Teo, 2010; Macintosh, 2004). This, in turn, increases government effectiveness, accountability, and quality (Von Haldenwang, 2004; Shirazi, 2008; Northrup and Thorson, 2003). ICT also promotes transparency and openness, which reduces corruption through better governance, reform initiatives, stronger citizen-government relations, and monitoring of government employees' activities (Bertot et al., 2010; Shim and Eom, 2008). Further, expanding ICT coverage in cities reduces the digital divide (Rallet and Rochelandet, 2009). ICT infrastructure may exert the opposite impact on inequality. On the one hand, it can aggravate inequality by uneven accessibility (Hargittai, 2003) or by increasing the demand for skilled labour resulting in widening the wage gap *"job polarisation"* (Richmond and Triplett, 2018; Falck et al., 2016). On the other hand, as mentioned above, ICT boosts economic growth offering various opportunities to combat poverty by enhancing access to resources, information and markets and increasing firms' productivity and revenues (Jensen, 2007; Aker and Mbiti, 2010).

2- ICT use facilitates information sharing, which is critical for entrepreneurs who utilise information and spillovers to seize new opportunities, mitigate risks, and access crowdfunding (Shane and Venkataraman, 2000; Shi and Wang, 2017; Mollick and Kuppuswamy, 2014; Ye et al., 2018). Internet use provides an environment that flourishes creativity (Shoshani and Hazi, 2007) and stimulates civic participation (Morris, 2000; Boulianne, 2009). The Internet facilitates e-commerce and remote work applications that reduce pollution through lower energy consumption and less waste, i.e., less travel time and printed marketing materials (Romm, 2002; Coroama et al., 2015). In addition, the Internet is an effective tool for citizens to engage in socio-political activities through e-participation (Zheng and Schachter, 2017; Stieglitz and Brockmann, 2013) and for civil society to share their agendas and expand their connections (Sey and Castells, 2004; Haythornthwaite, 2005; Warkentin, 2001). Healthcare is also improved through assistance with chronic disease management, remote medical services, and continuous monitoring of patients and the elderly

(Patrick et al., 2008; West, 2012). Moreover, mobile applications with real-time data provide information about traffic conditions, resulting in less congestion in the city (Pešić and Kojić, 2012). While higher mobile subscriptions can potentially reduce pollution through their various applications, they contribute significantly to the overall carbon footprint (Fehske et al. 2011).

3- The quality of transportation infrastructure improves access to transportation networks, which increases urban productivity and employment (Duranton and Turner, 2012; Holl, 2016). Further, better transportation and green infrastructure can potentially alleviate air pollution impacts, reduce traffic congestion, and improve health (Nelson et al., 2007; Dröes et al., 2015; Albalate and Fageda, 2019; Kumar et al., 2019; Hartig et al., 2014). Participation in social and public life is enhanced by better transportation infrastructure, especially for marginalised groups, such as the disabled, low-income people, and women, who have better and safer access to all parts of the city (Delbosc and Currie, 2011; Stanley and Stanley, 2017). Infrastructure quality enhances poorer citizens' access to economic and social opportunities and, in turn, exerts a positive impact on their income (Puga, 2002).

4- Green innovations, such as renewable technologies imply a higher share of employment in knowledge-intensive sectors (Domenech et al., 2016), higher productivity due to their environmental advantages (Chen et al., 2006), and better environmental quality (Kemp and Foxon, 2007).

5- The transition to renewable energy requires adapting new technologies and a skilled workforce, promoting TFP growth, economic diversification, employment in related sectors, and efficient infrastructure (Al Mamun et al., 2018; Sohag et al., 2021). This transition reduces greenhouse gas emissions and combats climate change, improving the quality of citizens' health (Tugcu and Tiwari, 2016; Buonocore et al., 2016).

6- Waste treatment preserves the environment and natural resources (Sandulescu, 2004). In addition, treating hazardous waste helps reduce its impact on the health of individuals (Misra and Pandey, 2005).

7- Education has many relationships: a- High levels of education and skills stimulate R&D activities and technical innovation (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1998; Chi and Qian, 2010; Grassi and Di Cintio, 2012). b- The level of human capital is crucial for increasing TFP growth through

knowledge spillovers and job search externalities (Lucas, 1988; Acemoglu, 1996, De la Fuente and Doménech, 2006; Jones, 2014). c-d-e-f Education builds the necessary knowledge that fosters entrepreneurial activity (Bodman and Le, 2013), plays an important role in the transition to a knowledge-based economy that increases employment in knowledge-intensive sectors (Collet et al., 2015), smooths the transition of workers between different sectors, which enhances labour market flexibility (OECD, 2017), and improves research productivity, which is reflected in patent applications (De Rassenfosse and De La Potterie, 2009). g- Education develops individuals' creativity (Baer and Kaufman, 2006; Wegerif, 2010), is related to Internet use (Gong et al., 2007), and has a significant impact on citizen participation through the acquisition of political knowledge and civic skills (Nie et al. 1996; Bovens and Wille, 2010; Kenski and Stroud 2006). h-i-j- High levels of education create environmental awareness among citizens, which leads local governments to adopt green policies and change their energy consumption patterns toward more efficient resources (Grossman and Krueger, 1991; Mahalik et al., 2021). Education also enables the development of technical solutions, such as renewable energy, that contribute to better environmental quality (Hess and Collins, 2018). k- Educated people have skills and information about potential incidents that improve their health (Pappa et al., 2009, and promote practices to combat discrimination and social exclusion (UNESCO, 2016). l- Education significantly reduces crime rates when educated people are more engaged in their communities and respect social values (Creed et al.,2001; Billings et al.,2014). Further, education is associated with labour market participation, so committing a crime has a higher opportunity cost for educated people (Buonanno and Leonida, 2006). m- Education increases e-participation by building technical skills, such as Internet use and increasing individuals' political awareness (Morris, 2000; Anduiza et al., 2010; Zheng and Schachter, 2017). It also improves the citizens' socioeconomic status, increasing participation in civil society (Campbell, 2006). n- Education has an ambiguous effect on inequality. On the one hand, it exacerbates income inequality initially through changing labour composition and increasing skilled labour 'composition effect'. However, it can suppress inequality due to an increase in the supply of educated people lowering wage premium for skilled employees 'wage compression' (Gregorio and Lee, 2002).

8- Digital literacy promotes ICT use and, consequently, the digital divide (Maji and Laha, 2021). Moreover, the skill premium for digital skills is the main reason for increasing income inequality (Nahuis and de Groot, 2003).

9- Creativity is linked to the following indicators: a-b-c-d- Creativity expands the nation's innovation capacity, increases productivity, and promotes entrepreneurial activities and labour market flexibility by introducing new ideas and expanding the skills of the labour force (Lee et al., 2010; Cerisola, 2019; Rodriguez-Pose and Lee, 2020; Lee et al., 2004; Bosch et al., 2017). e- Patents result from creative processes (Audia and Goncalo, 2007). f-g- The experiential creative sector has a low environmental impact, and creativity motivates environmental protection by stimulating community engagement and awareness of environmental challenges (Beer et al., 2018). h- Creativity positively impacts mental and physical health and destructive behaviours through its therapeutic effects, stress reduction, and creation of strong social bonds (Thoits and Hewitt, 2001; Palmar and Nascimento, 2002; Guetzkow, 2002). i-j Creativity promotes diversity, communication, and sharing of experiences. This provides opportunities for people from different backgrounds to share their concerns and participate in collective actions with local government and non-governmental organisations, which enhances social inclusion and civil society participation (Barraket, 2005; Guetzkow, 2002).

10-11- The relationships between innovation and the other indicators in the framework are identified as follows: a- the link between innovation and productivity has been established since endogenous growth theory, in which cumulative R&D increases the stock of knowledge, which in turn increases the productivity level of the economy (Mansfield, 1980; Griliches, 1988; Romer, 1990; Grossman and Helpman, 1991). Therefore, the ability of firms to integrate new technologies into their production process is a major source of productivity that exceeds traditional investments in physical and human capital (Sala-i-Martín, 2016). b- R&D activities create knowledge spillovers that open up new opportunities for entrepreneurs who turn these innovation opportunities into profit (Audretsch et al., 2006; Sanders, 2007). c- Innovative ecosystems facilitate knowledge creation, which increases the employment rate in knowledge-intensive activities, given that there is no change in total employment (Domenech et al., 2016). d- Regarding the impact of innovation on labour market flexibility, as measured by the unemployment rate, there is no simple relationship

between innovation and employment change, as the type of innovation influences this relationship. R&D expenditures lead to two types of innovation, process and product innovation, the former involving a change in the technology used to produce goods and services and the latter involving the production of new, updated products. Thus, innovation has a positive effect on employment when new or updated products are brought to market (Edquist et al., 2001; Freeman et al., 1982; Vivarelli and Pianta, 2000). Process innovation, on the other hand, makes better use of resources, which increases labour productivity and has a negative impact on employment levels (Domenech et al., 2016). However, sometimes process innovation aims at improving quality rather than saving labour, which has the opposite effect on employment (Peters, 2004). In fact, the rate of innovation can affect labour market flexibility through its impact on investment in human capital in the form of training and learning-by-doing (Acemoglu, 1997). e- R&D requires continuous creativity to deal with complicated situations (Hemlin, 2013) f- Green R&D investment and eco-innovation increase capacity, replace production with environmentally friendly resources, and reduce pollution (Cole et al., 2005; Lee and Min, 2015). g-h-i- R&D expenditure concomitant with spillover effects promotes the development of renewable energy, green technologies, and waste treatment processes (Gan and Smith, 2011; Miremadi et al., 2019, Liu et al., 2020). j- Integrating technologies, such as nanotechnology into healthcare improves existing processes, diagnoses, treatments, efficiency, and thus life expectancy (Govindarajan, 2007; Varkey and Athyal, 2005). k- Higher R&D investment signals technological advancement in the economy, with investment in ICT infrastructure yielding higher returns than other non-ICT-related investments (Mohan, 2007; Koutroumpis et al., 2020). r- R&D spending is a sign of technological progress in the economy and lowers the cost of ICT services, promoting ICT use (Mohan, 2007; Nair et al., 2020). R&D expenditure and ICT use are closely related, as increasing knowledge diffusion requires extensive Internet use to disseminate that knowledge (Choi and Yi, 2018). l-m-n- ICT innovations facilitate the implementation of e-government (Warkentin et al., 2002; Siau and Long, 2009). Further, technologies, such as the Internet and mobile phones enable citizens to participate in the political and administrative process through e-participation (Weber et al., 2003; Clift, 2004; Bertini et al., 2009). o- Innovation increases income disparity by creating jobs for high-

skilled employees (Breau et al., 2014) and generating capital gains for innovators (Aghion et al., 2019).

12- The relationships between entrepreneurship and other indicators in this framework are as follows: a- Entrepreneurial activities drive innovation through knowledge creation (Veeraraghavan, 2009). Indeed, entrepreneurs are more incentivised to innovate and commercialise their new ideas by starting new businesses than incumbent firms that have already generated profits from their existing products (Audretsch, 1995; Klepper, 2009). b- Entrepreneurs increase productivity through creative destruction, where new businesses replace existing ones and translate their innovations into technological change (Schumpeter, 1934; Aghion and Howitt, 1990). Also, the possibility of new firms entering the market leads incumbent firms to improve their processes and thus increase their productivity (Baumol et al. 1988). c- Entrepreneurs create new employment opportunities by creating markets (Ghak et al., 2021). d- Entrepreneurs extensively use the internet to expand their export activities and improve their performance (Mostafa et al., 2005; Carayannis et al., 2006; Tiarawut, 2013). e- An entrepreneurial environment fosters individual and team creativity (Fillis and Rentschler, 2010). f- Entrepreneurship is associated with higher income inequality (Halvarsson et al., 2018; Atems and Shand, 2018) since entrepreneurs have a higher saving rate due to their irregular income leading to wealth concentration (Meh, 2005), higher work effort due to borrowing and financial constraints the face resulting in higher income and capital accumulation for entrepreneurs (Jones and Kim, 2017).

13- Employment in knowledge-intensive sectors is associated with higher innovation compared to other sectors because it relies on R&D activities, analytical knowledge, and patenting (Tödtling et al., 2006; Schneider et al., 2010). Additionally, a knowledge-intensive environment, such as the ICT sector contributes to technological progress, leading to higher productivity (Seki, 2008), elevating entrepreneurial activities, and increasing labour demand (Audretsch et al., 2019). Another characteristic of employment in knowledge-intensive sectors is their reliance on ICTs, such as the Internet (Billon et al., 2017) and their lower environmental impact compared to manufacturing sectors (Nurmi, 1998).

14- An effective government stimulates R&D investment in private and public firms by supporting and subsidising innovation processes (Alam et al., 2019;

Mahmood and Rufin, 2005), incentivises efficient resource use and technological advances to improve productivity (Olson et al., 2000), provides effective fiscal policies to encourage entrepreneurial activity (Jiao et al., 2015), improves the business environment by reducing bureaucracy and ensuring sound regulation (Çule and Fulton, 2013), increases labour market flexibility by improving administrative capacity and the quality of regulation (Knack, 1999), and promotes patent registration through better law enforcement and intellectual rights (De Rassenfosse and de la Potterie, 2009; Jiao et al., 2015; North 1990). Further, government effectiveness is vital in improving education and health through efficient public spending (Rajkumar and Swaroop, 2008; Hauner and Kyobe, 2010). Accountable governments and fair institutions promote citizen participation in policy decisions (Doherty and Wolak, 2012; Lind and Tyler, 1988) and establish inclusion policies so all populations can access public services (Lewis, 2006). Well-functioning institutions can also improve environmental quality by implementing pollution control strategies, setting environmental policies, investing in renewable energy, expanding green spaces, and using fiscal transfers to support municipal waste collection and treatment (Wu, 2017; Polzin et al., 2015; Fors et al., 2015; OECD, 2021). Through efficient investment in transportation infrastructure, guided by effective decision-making and good public management, an effective government improves the quality of the transportation network (Crescenzi et al., 2016) and develops and deploys ICT infrastructure effectively (King et al., 1994). An effective government implements e-government to respond to citizens' needs, provide public services online, and improve government openness, transparency, and efficiency (Suhardi et al., 2015; Tolbert and Mossberger, 2006). It also encourages e-participation by increasing the level of confidence in government (Kaufmann et al., 1999; Brooks, 2002), reduces the digital divide by employing fiscal policies, such as providing tax incentives and subsidies to encourage private sector donation of ICT equipment, expanding broadband networks in cities; community ICT training (Cullen, 2001), addressing privacy issues by enacting privacy regulations and laws (Chang et al., 2018). Finally, an effective government is vital to reducing income inequality through fiscal redistribution in income taxes and social transfers (Chong and Calderon, 2000).

15- E-government supports productivity growth by eliminating market imperfections and improving capital accumulation and financial inclusion (Kpodar and

Andrianaivo, 2011; Faid et al., 2020). It increases the ease of doing business by reducing bureaucratic procedures, such as licensing and property registration (Martins and Viega, 2018) and facilitating new business creation and entrepreneurial activities (Schnoll, 2015; Besley, 2015). The successful implementation of e-government is related to the availability of skilled workers in knowledge-intensive sectors (Sharma and Gupta, 2003), as well as the availability and ability to access ICTs, such as the Internet. There is also a positive correlation between e-government, participation in public life, and social inclusion through better access to public services and democratic processes (Gajendra et al., 2012). E-government initiatives are crucial to increase government effectiveness as information flow improves public service delivery and civic participation and inclusion, which leads to better democracy (Al-Kibsi et al., 2001; West, 2004; Islam and Ehsan, 2015). Further, the interaction between citizens and government through e-government and e-participation motivates participation in civil society (Haller et al., 2011). Thus, e-government increases transparency by preventing corrupt behaviour by government officials (Bhatnagar, 2003; Shim and Eom, 2008).

16- Similar to e-government, e-participation utilises the Internet as a basis for communication between citizens and government (Sanford and Rose, 2007). This initiative enables greater participation and engagement in political processes, such as voter turnout (Sæbø et al., 2010; Ladner and Pianzola, 2010). As a result, greater participation can improve various aspects of urban life, such as environmental quality (Payne, 1995). E-participation also improves government effectiveness (Waheduzzaman and Khandaker, 2022) and government transparency (Von Haldenwang, 2004; Andersen, 2009).

17- Participation in civil society equips citizens with civic skills that increase their participation in public life (Verba et al., 1995; Putnam, 2000; Dubow et al., 2017). The involvement of these organisations plays a crucial role in increasing available knowledge, raising public awareness, and devising policy formulations on various issues, such as environmental protection, energy transition, green areas development, and sustainable development (Pelletier et al. 1999; Holmes and Scoones 2000; Smith, 2012; Mumtaz, 2021). Besides, civil society influences public behaviour and cooperation with public institutions, which can reduce crime rates (Ralchev, 2004). By connecting community and government, involving the community

in decision-making, and helping to keep public spending and procurement efficient, civil society organisations increase government accountability, effectiveness, and transparency (Arko-cobbah, 2006; Scholte, 2004; Malena and McNeil, 2010; Bernauer et al., 2016). Finally, civil society participation may help reduce inequalities by promoting and advocating human rights, providing basic needs to vulnerable groups, monitoring progress and informing policies (Anheier, 2004).

18- Health positively affects productivity because healthy workers are less likely to be absent from work, save, and invest more in education, leading to higher earnings and physical capital accumulation (Bloom and Canning, 2000).

19- Crime negatively affects many aspects of the business environment, including investment in R&D (Pshisva and Suarez, 2006), productivity as firms reallocate resources to fighting crime rather than investing to expand business (Detotto and Otranto, 2010), and discouraging entrepreneurial activity (Porter, 1997; Ortega Alvarez, 2002). Crime also affects civic participation and cooperation among citizens (Saegert and Winkel, 2004) and physical and mental health due to stress and anxiety (Fischbach and Herbert, 1997; Freeman and Smith, 2014; McManus, 2001).

20- Traffic congestion reduces productivity through frequent delays, higher costs of operating vehicles, and increasing emissions (Koźlak and Wach, 2018). It also affects the health of citizens and degrades the environment (Monzon, 2015).

21- Pollution reduces worker productivity, especially in physically demanding jobs (Chang et al., 2016). Moreover, resource depletion affects productivity as a factor of production decline (Camagni et al., 2013). Pollution also has extreme impacts on health quality, such as the risk of asthma and premature mortality (Currie and Neidell, 2005; Pope et al., 2002; Bell et al., 2004).

22- It is argued that productivity growth increases GDP, making more resources available for innovation (Vakhitova and Pavlenko, 2010; Damijan et al., 2011). Moreover, ceteris paribus, the higher the productivity growth rate, the lower the unemployment rate in the long run due to the *"capitalisation effect"* (Pissarides, 2000).

23- The relationships between labour market flexibility and other indicators are as follows: a- Labour market flexibility has opposite effects on innovation. On the one hand, higher flexibility leads to underinvestment in job training, as competitors can grasp this instead (Kleinknecht, 1998). This prevents firms from fully utilising their

capacity, leading to a negative relationship between innovation and labour market flexibility (Grant, 1991; Michie and Sheehan, 2003). On the other hand, flexible employment allows the use of external labour inputs and introduces new knowledge that can promote innovation (Teece, 1986; Zhou et al., 2011). b- Labour market flexibility has a positive impact on productivity, as it facilitates the reallocation of labour to more productive sectors (Lucidi, 2008). c- Lower labour market flexibility impedes individuals from finding suitable jobs encouraging them to engage in entrepreneurial activities (Fritsch et al., 2015; Dvouletý and Mareš, 2016; Dvouletý, 2017). d- Participation in public and social life is hindered when individuals suffer from financial hardship due to unemployment (Jenkins and Cappellari, 2007). e-f-g- Exclusion from the labour market is associated with psychological and health problems (Evans and Repper, 2000), increases the likelihood of participation in criminal activities (Freeman, 1999) and social exclusion (Evans and Repper, 2000). h- Higher unemployment rate tends to worsen the position of low-income citizens, increasing the income gap (Mocan, 1999).

24- A transparent and anti-corruption government fosters innovation, increases R&D expenditure, supports higher patenting by constituting intellectual rights, and reallocates resources to more efficient activities by eliminating rent-seeking activities (Xu and Yano, 2017; Baumol, 1990; Lambsdorff, 2003). Corruption control reduces uncertainties and asymmetries in the economic environment and improves the ease of doing business, incentivising entrepreneurs by allowing them to capture a higher share of profits (Anokhin and Schulze, 2009; Nageri and Gunu, 2020). A transparent government combats bribery and nepotism, which reduces unemployment rates (Dwivedi, 1967). Further, transparent and accountable governments have better quality and allocation of public services and social expenditures, such as education, cultural facilities, and health care (Sacks and Levi, 2010; Gupta et al., 2002; Delavallade, 2006). On the other hand, corruption discourages participation in public life because citizens lack trust in state institutions and their legitimacy (Kostadinova, 2009; Seligson, 2002). Additionally, transparent and stable governments are associated with better environmental quality (Zugravu et al., 2009; Wu, 2017), higher renewable energy production (Cadoret and Padovano, 2016), efficient infrastructure (Kenny, 2009), and lower crime rates (Holmes, 2009). Government transparency enables the development of e-government initiatives

(Aladwani, 2016; Pathak et al., 2007) and facilitates effective citizen participation and involvement in the community (Sapsford et al., 2019). Finally, good policymaking regarding transparency and openness is linked to open data and information sharing when governments become accountable to citizens. Monitoring the government concomitant with available data improves the government's ability to formulate sound policies and allows for better coordination among institutions, hence, increasing their effectiveness (Islam, 2006). Finally, government transparency improves income inequality through its role in resource distribution, providing equal access to economic opportunities, and enhancing market efficiency and information access (Islam and McGillivray, 2019; Chia et al., 2022).

25- The digital divide limits individuals' access to online education, excludes them from participating in digital initiatives, limits employment opportunities, and exacerbates income inequality as individuals with digital skills earn a higher income (Norris and Conceicao, 2004; Ribeiro et al., 2018; Noh and Yoo, 2008).

26- Security and privacy issues raise concerns for citizens about participating in e-government services (Cremonini and Valeri, 2003). They pose big concerns about using commercial websites and even more concern for citizens engaging with e-government services, which leads to a lack of trust, which is a significant barrier to adopting e-government (Cremonini and Valeri, 2003).

27- The lack of freedom of expression and other restrictions on civic space are seen as major barriers to e-participation (Wakabi and Grönlund, 2015).

28- Higher levels of income inequality have been associated with higher crime rates, lower educational attainment (Checchi, 2001), poorer health, lower democracy, digital divide (Stiglitz, 2012; Wilkinson and Pickett, 2011; Attewell, 2001; Bonfadelli, 2002; Ekdahl and Trojer, 2002), and low levels of civic participation (Lancee and Van de Werfhorst, 2012). Further, greater inequality can lead to environmental degradation through several channels. First, affluents tend to own polluting businesses and can influence policy in addition to their higher consumption, which contributes to pollution (Boyce, 1994). Inequality also makes it more difficult to enforce environmental policies (Borghesi, 2006). The impact of inequality on entrepreneurship is mixed. On the one hand, the supply-side approach holds that inequality creates a class of wealthy individuals who can take high risks and invest in new ventures (Atems and Shand 2018; Packard and Bylund 2018). On the other hand, the demand-side

approach argues that reducing inequality and increasing budget constraints on citizens reduces the purchasing power of the economy and the availability of human and financial capital needed to start businesses (Auguste 2020; Gutiérrez-Romero and Méndez-Errico 2017; Xavier-Oliveira et al., 2015).

### 1.5. A Conceptual Framework For Mapping The Interlinkages Among Smart City Indicators

Several attempts have been made in various fields to conceptualise the characteristics and practices of smart cities and to compare the performance of cities using different methods, including, among other things, benchmarking, assessment against peers, baseline assessment, and maturity models (Kitchin et al., 2015). Researchers have argued that modelling a smart city requires first a clear grouping of its components into multiple dimensions to structure its complex interactions (Kanter and Litow, 2009). One strand of research focuses on identifying the key components that make a city smart (Ben Letaifa, 2015; Nam and Pardo, 2011).

Others classify smart city concepts according to several smart dimensions. Among the attempts at such grouping was by Komninos (2011), who emphasised the use of ICT infrastructure to improve innovation and disseminate knowledge in the city. However, subsequent researchers, such as Lombardi et al. (2012), Chourabi et al. (2012), Bosch et al. (2017), and Joss et al. (2019) integrated different underlying and overlapping dimensions of urban life, i.e., people, institutions, economy, society, and so on. Most of these frameworks report common dimensions, such as smart people, smart governance, and smart mobility and assume that their common synergy will lead to economic benefits. Other aspects, such as culture, safety, and health, are less common (Neirotti et al., 2014) and integrated into other dimensions, such as smart living. Table 1.5 enumerates the smart city conceptualisation proposed by different researchers. According to the table, the most common dimensions of smart cities are ICT infrastructure, smart economy, governance, and the natural environment.

The above discussion shows that the major drawback of many frameworks is to break down the smart city concept into many dimensions and indicators without considering the complex interlinkages and interdependencies of these indicators in a *processual* and *ordered* manner using a *systemic* approach. In fact, the identification

of indicators is not sufficient to create a smart city, as it should be treated as an organic whole. Moreover, existing research highlights the benefits of smart cities but neglects the negative externalities associated with their implementation, which need to be addressed. Another research gap is the limited application of a *systemic analysis* of the interactions between smart city indicators based on a *quantitative* technique. This shortcoming significantly weakens the reliability of the empirical results as either all related variables are not included in the analysis, leading to omitted variable bias, or the relationships between the variables are investigated disregarding their multidimensional and complex interconnections for the sake of theoretical abstraction.

Therefore, the successful implementation of this urban development model, smart cities, requires not only the identification of their key drivers, i.e., digitalisation, institutions and socio-economic factors but also an understanding of their direct and indirect impacts on smart city outcomes. To this end, a processual conceptual and quantitative investigation between the inputs and outputs of a smart city system is provided. The processual approach emphasises that smart cities are not just a collection of technologies but rather a complex and dynamic system that encompasses a range of inputs, processes, and outputs. Therefore, network analysis is utilised to establish the systematic interactions between smart city drivers and policy outcomes in a complex framework. Figure 1.1 shows the research frameworks of the smart city indicators' interlinkages.

**Table 0.5:** The list of Smart city frameworks in the literature.

| Study | Dimensions |
|---|---|
| Joss et al. (2019) | Digital technology; infrastructure; governance; economy; society; spatial planning/development; environment; sustainability; experimentation/innovation; international |
| Bosch et al. (2017) | People; planet; prosperity; governance; propagation |
| Petrolo et al. (2017) | Governance; people; economy; living; environment; mobility; technology |
| Gil-Garcia et al. (2015) | Public services; city administration and management; policies and other institutional arrangements; governance, engagement and collaboration; human capital and creativity; knowledge economy and pro-business environment; built environment and city infrastructure; natural environment and ecological sustainability; ICT and other technologies; data and information. |
| Mosannenzadeh and Vettorato (2014) | Governance; people; economy; environment; mobility; technology |
| Neirotti et al. (2014) | Governance; people; economy; living; environment; mobility; technology; education; healthcare; safety; culture |
| Chourabi et al. (2012) | Governance; management; policy; people; economy; environment; technology |
| Kunzmann (2014) | Technology; community; policy |
| Dameri (2012) | Governance; people; living; environment |
| Balakrishna (2012) | Governance; people; economy; environment; mobility; technology |
| Barrionuevo et al. (2012) | Economy; people; social; environmental; institutional |

| | |
|---|---|
| Kourtit and Nijkamp (2012) | Human capital; infrastructural capital; social capital; entrepreneurial capital |
| Ambrosetti (2012) | Mobility management; resource management, quality of life |
| Nam and Pardo (2011) | Governance; people; technology |
| Washburn et al. (2009) | Governance; living; mobility; technology; education; healthcare; safety; culture |
| Komninos (2008) | Skills; knowledge; spaces; innovation |
| Giffinger et al. (2007) | Governance; people; economy; living; environment; mobility |

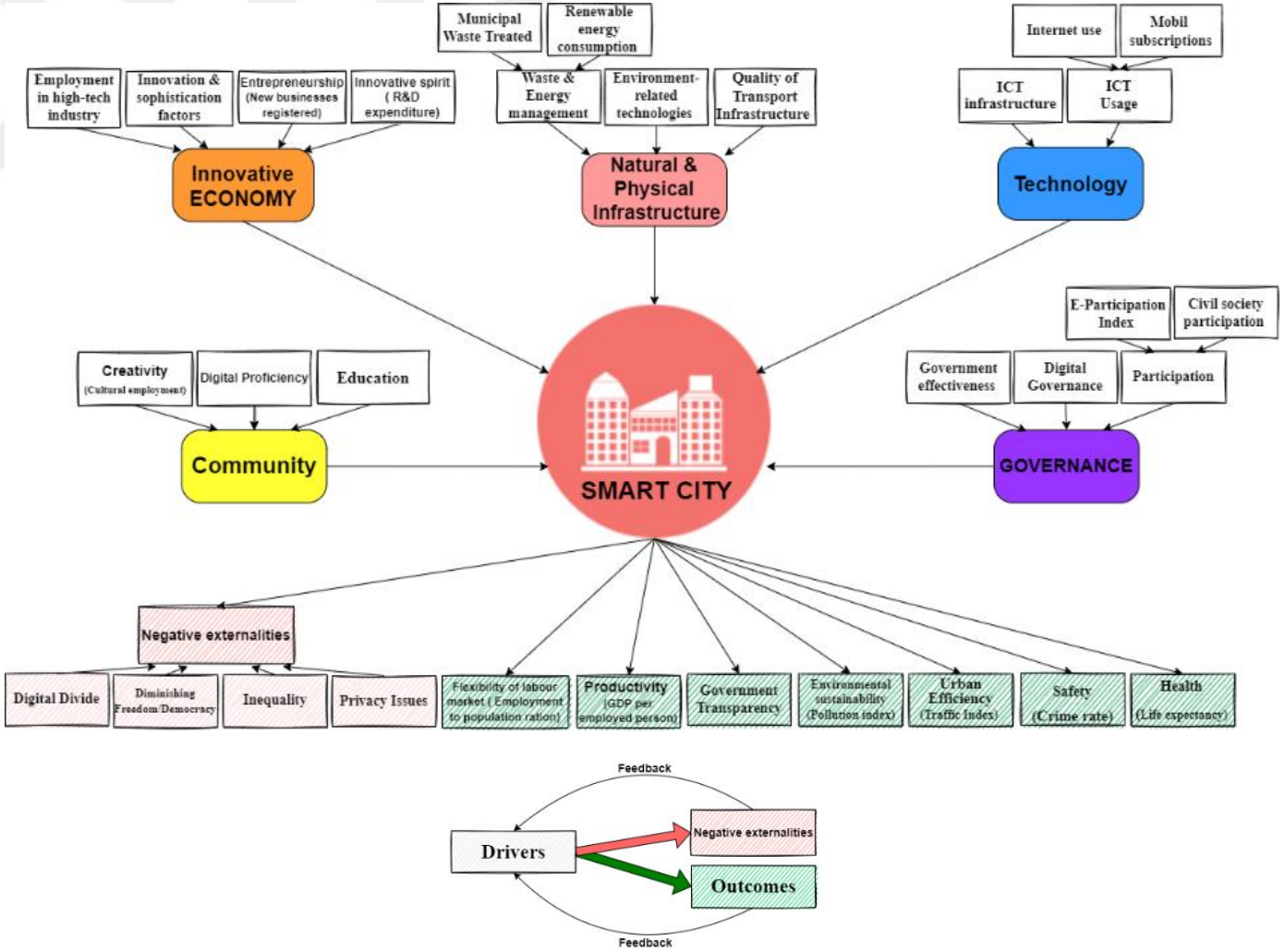



**Figure 0.1:** The research first framework.

## 1.6. Ranking Schemes For Smart Cities

The multidimensionality of smartness, containment with the complexity of cities and urban metabolism, requires a specific assessment technique that can capture the different dimensions of smartness and the interactions between social, political, economic, and cultural aspects of cities and the built environment. Many approaches to assessing the smartness of cities have been developed according to the different conceptualisations of the concept. These include the use of indicators, indices, and city rankings.

Although indicators may seem rigid or insufficient to capture the complexity of cities (Holden, 2013), they have been increasingly used by city managers and policymakers over the last 20 years to assess cities' competitiveness, development, and attractiveness (Berardi, 2013). In specific, the comparative analysis evaluates cities according to their different dimensions and ranks them to identify frontrunners and laggards based on different indicators that are considered simple and clear to understand, compare and visualise.

Rating approaches based on synthetic quantitative indicators offer several advantages for different stakeholders, including governments, investors, researchers, and citizens. First, city governments can utilise these indicators to monitor city performance, which can enhance the international image and competitive position of cities (Huovila et al., 2016; Mohan et al., 2017); legitimise investments and smart city initiatives (Caird et al., 2016); map the strengths and weaknesses of cities to guide their planning and development priorities (Garau and Pavan, 2018; Zygiaris, 2013); track progress towards smartness goals and targets (Garau and Pavan, 2018); identify the technical requirements and socio-economic and environmental impacts of smart city projects (Sang et al., 2015); identify best practices from peers' experiences (Debnath et al., 2014; Giffinger et al., 2010); improve the transparency of governance (Debnath et al., 2014; Giffinger et al., 2007), shape debates and policy roles by diversifying policy options using the new data (De Sherbinin et al., 2013); and support decision-making regarding resource mobilisation (Barsi, 2018).

Second, investors can use the indicators and benchmarking as an evidence-based assessment for projects (Caird et al., 2016) to prioritise funding (Mohan et al., 2017) and identify the best locations for investment and new business opportunities (Airaksinen, 2016; Mohan et al., 2017). Third, researchers can develop new policies to improve the performance of smart cities (Caird et al., 2016) or break down the complexity of the smart city concept (Akande et al., 2019). Finally, indicators raise citizens' awareness of the benefits of smart city initiatives (Caird et al., 2016) and promote engagement in smart city development activities (Airaksinen, 2016; Debnath et al., 2014).

Previous research has explored the nature of indicators, their thematic focus, and challenges related to assessment tools. For example, Albino et al. (2015) provide a brief overview of smart city ranking tools and frameworks, such as the University of Vienna, the Intelligent Community Forum's Smart 21 Communities, the Global Power City Index, the Smarter Cities Ranking, the World's Smartest Cities, the IBM Smart City, and the McKinsey Global Institute rankings. Similarly, Caird et al. (2017) examined other frameworks including the Smart City Maturity Model, the Smart City Reference Model, the European Smart Cities Ranking Model, the Smart City Index Master Indicators Framework, the Ericsson Networked Society City Index, the Smarter City Assessment Tool, and the Cities of Opportunity Index. Table 1.6 provides a list of selected smart city ranking schemes.

Another assessment tool has been developed by the Intelligent Community Forum, which annually benchmarks the top 21 smart communities based on broadband connectivity, skilled workforce, digital inclusion, innovation, and marketing and advocacy (Albino et al., 2015). Lazaroiu and Roscia (2012) proposed a method for ranking smart cities to help determine European funding allocations in the 2020 Strategic Plan. The researchers used a fuzzy approach to determine the weighting of indicators according to their relative importance.

The Japanese Institute for Urban Strategies has introduced the Global Power City Index to rank global cities according to their *"magnetism"* or potential to attract people, capital, and business. It includes six criteria, namely economy, research and development, cultural interaction, quality of life, environment, and accessibility. The Cities in Motion index includes 77 city indicators spread across ten categories, including economy, technology, human capital, social cohesion, international outreach, environment, mobility and transport, urban planning, public administration,

and governance (Berrone et al., 2016). Allam and Dhunny (2018) proposed a new framework that includes technology alongside other key dimensions of culture, metabolism, and governance to assess smartness.

Giffinger et al. (2007) developed one of the best-known assessment tools to evaluate 70 medium-sized European cities against specific indicators for each smart city dimension, namely smart governance, smart economy, smart people, smart environment, smart living, and smart mobility. In addition, Sharifi (2019) analysed the performance of 34 smart city ranking tools and mapped the strengths and weaknesses against eleven criteria, including comprehensiveness, stakeholder engagement, context sensitivity, strategic need, uncertainty management, interlinkages and interoperability, temporal change, flexibility, feasibility, presentation and communication, and action plans.

Other stands of research investigate the thematic focus and typology of indicators (Huovila et al. 2019; Ahvenniemi et al., 2017; Sharifi, 2019). For example, Stratigea et al. (2017) compiled a comprehensive list of smart city indicators by examining five international frameworks and classifying the indicators into six broad themes, following Giffinger's classification. Their results showed a lack of ICT indicators in the selected assessment tools, with an extensive focus on the themes of living and environment, such as in the Smarter Cities Ranking developed by the US Natural Resources Defence Council and fewer indicators for the themes of governance and people. These findings were confirmed by Liao et al. (2017), who examined the indicators used in Chinese cities and found that they lack the smart dimension, making them unsuitable for developing smart city strategies.

In contrast, Ahvenniemi et al. (2017) have shown that social and economic indicators dominate among smart city indicators, while environmental indicators are absent. Huovila et al. (2019) examined seven indicator frameworks and introduced five types of indicators, namely input, process, output, outcome, and impact. Their analysis showed that smart evaluation tools consistently used output and outcome indicators, while process and impact indicators were used somewhat less.

Generally, the first step in developing an assessment tool is to identify a set of appropriate indicators. These can be selected based on a literature review, expert survey, or stakeholder consultation (Sharifi, 2019). Wu et al. (2016) investigated the different approaches used in the selection of assessment indicators and found that expert-based approaches, such as the analytical hierarchy process (AHP) were the

most commonly used technique in the selection of indicators. Second, aggregating the different types of variables into a smart index requires normalising the individual indicator values using techniques, such as the min-max or Z-score method (Wu et al., 2016). Then, the indicators are weighted differently depending on their importance to calculate the overall index score (Giffinger et al., 2010). However, the ranking of smart cities differs considerably among different schemes depending on the goals and objectives of the ranking, the selection of indicators, the thematic focus, the assessment methods, the quality and comparability of the data and the selection of cities (Schönert, 2003; Dangschat, 2001).

While the smart cities ranking raises public awareness of urban research challenges, triggers extensive debates on regional development strategies, improves the comprehensiveness and transparency of decision-making and triggers learning effects among local actors, there are also some potential drawbacks. First, the weakness of smart city rankings can be summarised as the problem of "*beauty contest"* and *"recursive self-affirmation"*, as echoed by Schönert (2003). In particular, rankings are discussed in terms of their final rankings, while the methodological aspects behind the ratings, the complex interrelationships and causalities are neglected.

From a strategic perspective, smart city rankings can hinder long-term development strategies and focus on short-term economic gains as increased competition between cities leads to lax regulation, structural and spatial challenges, etc. In this sense, cities with a high ranking, the winners, use these positive results to improve their public image and branding, in contrast to cities with a low ranking, the losers, which disregard benchmarking that could threaten their competitive position (Giffinger et al. 2010). In specific, cities will focus their urban policy efforts on their strengths and neglect their weaknesses. In other words, the general approach of smart city ranking aims at the simplicity of finding the most attractive city, which reinforces stereotypes and ignores the specific strengths and weaknesses of cities and their different contexts and activities (Giffinger and Gudrun, 2010).

From a technical point of view, the indicators' data are heterogeneous, which in addition to the correlation problem, poses a significant challenge to their comparability. Another challenge is the inclusion of qualitative indicators in the ranking scheme (Barsi, 2018). Most importantly, there is a lack of dynamic analysis, as all smart city rankings focus on the static state of urban smartness at a given point in

time. However, investigating the evolution or behaviour of cities and their interaction with the surrounding environment should reveal temporal changes, which requires a dynamic approach that can adequately capture the concept of smartness (Sharifi, 2019).

As discussed above, indicators have their own limitations and challenges, thus, other classification methods, such as factor analysis, have emerged. Factor analysis solves the problem of strong correlations between indicators and estimates the indicators closely related to the city's smartness (Barsi, 2018). The methodology of the study starts with the definition of the conceptual framework and the assessment system, followed by the selection of the drivers of smart cities based on an extensive literature review. Once the cities were selected, the data were normalised to remove the different ranges of variables. The indicators were then aggregated to produce a smart city score and ranking using dynamic factor analysis.

**Table 0.6:** List of selected smart cities ranking schemes.

| Ranking Scheme | Year | Source | Scope |
|---|---|---|---|
| **Innovation Cities TM (IC)** | 2011 | 2thinknow (www.2thinknow.com) | Global (330 cities) |
| **Smart Cities – European Medium-sized Cities (EMC)** | 2007 | Europe | 70 cities |
| **Cities in Motion Index** | Yearly basis | Center for Globalization and Strategy and IESE Business School's Department of Strategy | Global |
| **Assessing Smart City Initiatives for the Mediterranean Region** | 2017 | Universidad Politécnica of Madrid (UPM). | Mediterranean Region |
| **UK Smart Cities Index** | 2017 | Navigant Research | UK |
| **CITYkeys** | 2016 | Netherlands Organization for Applied Scientific Research (TNO) | Global |
| **Cities of Opportunity** | 2016 | PricewaterhouseCoopers (Pwc) | Global |
| **Smart Cities Ranking of European Medium-sized Cities** | 2014 | TU Vienna, in cooperation with the University of Ljubljana and the TU of Delft | Europe |
| **Global Power City Index** | Yearly basis | The Mori Memorial Foundation's Institute for Urban Strategies | Global |
| **Smart City Index** | Yearly basis | The IMD World Competitiveness Center | Global |
| **Juniper Research smart city frameworks** | Yearly basis | Juniper Research | Global |

## 1.7. A Conceptual Framework For Developing A Static And Dynamic Index For Smart Cities

In light of ongoing global urbanisation trends and the challenges facing metropolitan areas today, such as climate change, pandemics, rapid urbanisation, and ageing infrastructures, city leaders have recognised the need to shift from traditional urban planning and development models to more innovative and efficient models. Cities worldwide have begun to explore different solutions to address the challenges and complexities of cities and enhance public services and governance. In this context, smart cities have emerged as a panacea for urban sustainability, and many smart city projects have been rolled out and developed around the world so far (Huovila et al., 2019; Ahvenniemi et al., 2017; Angelidou, 2014; Caragliu et al., 2011).

These projects not only improve the intelligence of the socio-economic aspects of cities but also provide a plethora of benefits, including, inter alia, promoting competitive advantage (Giffinger et al., 2010), attracting talented and skilled citizens (Sharifi, 2019), improving transparency in governance (Nam and Pardo, 2011), transitioning to a low-carbon society (Huovila et al., 2017), boosting the quality of life (Manville et al., 2014) and accelerating progress towards the Sustainable Development Goals (Sharifi, 2019). The Business Research Company reported that the smart city market is expected to reach 2.5 trillion by 2026, with an annual growth rate of 18.22% from 2021-2026 (The Business Research Company, 2022). These projections indicate that city leaders are gradually embarking on smart city projects and solutions and consequently implementing smart city development policies (Kunzmann, 2020).

As the number of smart city projects continues to grow, there is also a notable boom in developing and implementing tools and indicators to assess their performance (Caird et al., 2016). The ranking was developed to support investors' investment decisions on the one hand and to guide cities in developing their strategies according to their strengths and weaknesses in order to foster their development and build a competitive position on the other (Giffinger and Gudrun, 2010; Lazaroiu and Roscia, 2012).

While smart city rankings have received much attention in recent years (Mäding, 2001; Giffinger et al., 2007; Patrão et al., 2020), studies have focused on measuring outcomes influenced by many other aspects rather than smartness itself. In this respect, the smart city concept also includes socio-economic and institutional

drivers. Therefore, assessment schemes should cover multiple influencing drivers rather than focusing only on technological indicators (Caird et al., 2016). In doing so, a comprehensive coverage of indicators enables a systems-based approach that captures the transformation of urban systems (Dirks et al., 2009).

Moreover, existing smart city ranking tools focus on a single time period, thus providing a snapshot in time and ignoring the development patterns of cities (Sharifi, 2019). Indeed, cities are not static, with many socio-economic and environmental mechanisms constantly changing their underlying dynamics. Accordingly, the assessment and ranking of smart cities should track these changes to understand their performance evolution and progress towards achieving their goals (Kourtit and Nijkamp, 2012). This knowledge-based instrument is essential for urban planners and policymakers to assess how smart initiatives impact urban dynamics, evaluate improvements over time, and adjust their plans as necessary (Barsi, 2018). To fill this gap, this research introduces a static and dynamic ranking of smartness employing the drivers of smart cities for 33 selected cities for the period 2005-2019 using dynamic factor analysis. Figure 1.2 presents the study's second framework.

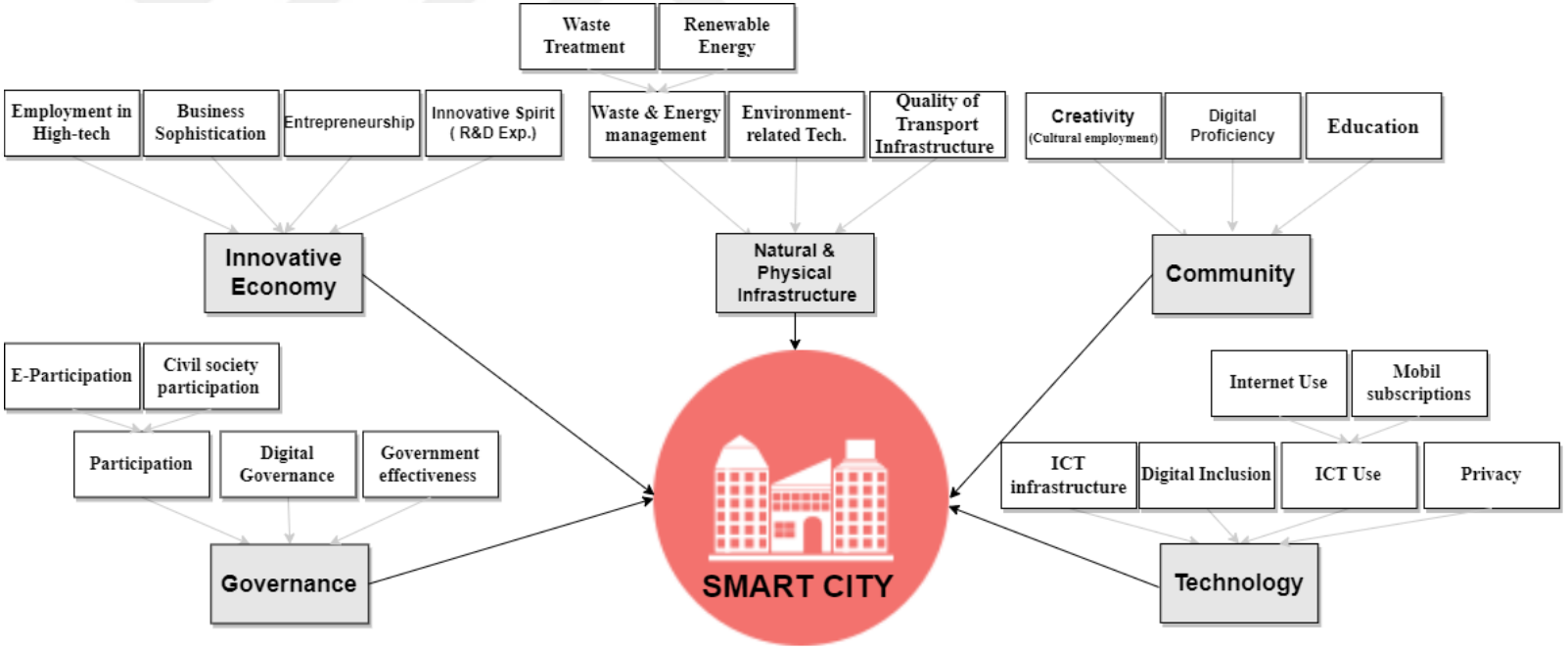



**Figure 0.2:** The research second framework.

# CHAPTER TWO
# THE CONCEPT OF SUSTAINABLE DEVELOPMENT

## 2.1. Definitions

Sustainable development has become the buzzword in the contemporary development paradigm. The concept has attracted great attention in governance, development planners, non-governmental organisations, and academia. While there is a plethora of definitions of sustainable development in the literature, determining the mechanisms for achieving sustainable development remains complex and controversial. Understanding the concepts underlying this paradigm is critical to developing strategies for transitioning nations to more sustainable forms of development.

### 2.1.1. The Concept of Development

The concept of development occupied an important place in politics, theories, and the race between capitalism and communism in the mid-20th century. Classical definitions of development captured the concept in economic terms, defining it as rapid growth in per capita income that brings economic and social benefits in the face of a growing population (Todaro and Smith, 2020). Others viewed development as the shift in production and employment structure from agriculture to manufacturing and services (Kuznets & Murphy, 1966; Lewis, 1954).

In the 19th and early 20th centuries, regions under colonial rule-now developing countries-made little economic and social progress as imperialists plundered their resources and exploited their cheap labour (Harris, 2000). This widened the gap between developed and developing nations and became the main concern of development researchers (Zimmerman, 1962). In addition, developed countries perceived economic growth as a means to their progress and neglected equity and social justice. Thus, many argued that sustaining international economic growth requires an equal distribution of wealth around the world, which could expand markets (Du Pisani, 2006). In particular, social and political concerns must be included in the development process in addition to economic resources. As a result, the concept of development with its normative perspective was redefined in the late 1970s to include issues, such as poverty, inequality, and unemployment in the growth

process (Todaro and Smith, 2020). The UNDP created the Human Development Index, which includes health and education as indicators of overall development in addition to GDP (Willis, 2011).

Neoliberal and modern development theories define the concept as a process that utilises its outputs to raise living standards and economic independence in the face of complex and integrated economic systems (Remeny, 2004). Peet and Hartwick (1999) define development as an *"evolutionary process in which the human capacity increases to initiate new structures, to cope with problems, to adapt to constant change, and to strive purposefully and creatively toward new goals".* Others viewed development as a process aimed at accelerating economic growth, reducing inequality, and eradicating poverty by changing existing institutions, behaviours, and social structures (Todaro and Smith, 2020). Another influential contribution of Sen (1999) was the inclusion of human rights and freedom in the concept of development and the definition of development in his capability approach as improving the well-being of individuals -particularly the poor - in terms of education, health, and standard of living rather than income. Several theories emerged that offer different explanations for the development concept, such as the modernisation theory and the dependency theory.

Modernisation theory explains the process of evolution and development within societies. It assumes that traditional societies dominated by indigenous culture, beliefs, values, and primitivism that hinder their development can evolve into modern societies that are progressive, industrialised, and cosmopolitan with high capital accumulation and mass consumption by emulating modern practises, institutions and structures adopted by developed nations (Knöbl, 2003; Gillman, 2018; Tipps, 1973). The gradual transition from a traditional to a modern society follows a common pattern of development that includes the adoption of advanced technology, democratisation, industrialisation, globalisation, and bureaucratic institutions (Marsh, 2014; Gillman, 2018).

Dependency theory, on the other hand, arose from the Marxists' rejection of modernisation theorists, who assumed that societies follow a similar path of development (Smith, 1979). Dependency theory emphasises that the underdevelopment of poor nations is the result of systematic neo-colonial profiteering of their resources, in which the 'core', i.e., wealthy nations, develop at the expense of the 'periphery', i.e. underdeveloped nations (Abhijeet, 2016; Webster, 1984;

Bodenheimer, 1970). Dependency theory thus states that developing nations should follow their own independent path to development, separate from the developed capitalist nations (So, 1990; Peet and Hartwick, 1999).

In the 1980s, structural adjustments were made in terms of opening up trade, reducing fiscal deficits, and controlling exchange rates. This shift from a government-centred development perspective to market-oriented policies improved economic efficiency but exacerbated inequality and led to worsening the poor's condition. On the global scale, development had unequal benefits for countries on the one hand and exacerbated environmental problems on the other. These challenges posed a major threat to the perceived success of development and required a rethinking of the concept and goals of development. As a result, a new development paradigm emerged, sustainable development, which includes environmental protection and social justice.

### 2.1.2. The Concept of Sustainability

The concept of sustainability can be traced back to 1713 when Hans Carl von Carlowitz took up the term in forestry to emphasise that forestry resources should be preserved over the long term (Scoones, 2007). It was chosen to bridge the gap between development and the environment (Rogers et al., 2007). The concept of sustainability has become so widespread that it can be applied to almost every facet of life, from the local to the global scope and across different periods. The meaning of sustainability varies greatly depending on the context in which it is used, e.g., from an economic, social, or ecological perspective (Brown et al., 1987). Broadly speaking, sustainability means the capacity to preserve the diversity and productivity of systems over time (Basiago, 1998).

From an economic perspective, sustainability means avoiding disruption and degeneration and ensuring stability and continuity (Costanza and Patten, 1995). In other words, the relationship between the economy and natural capital is the focal point for economists, who thus laid the foundation for the emergence of 'ecological economics' (Vos, 2007). In a sense, sustainability takes a temporal perspective and considers longevity as its primary concern. Ecologists use the term sustainability to describe the rate at which resources are depleted through pollution without compromising ecosystem integrity, i.e., ecosystem productivity (Vos, 1997; Shearman, 1990). Others, such as Gallopín (2003), approach sustainability from the

perspective of systems theory. For example, Ben-Eli (2018) defined sustainability as a dynamic equilibrium of the relationship between the carrying capacity of a system and its demography, in which the latter can fully develop without compromising the system's carrying capacity.

Further, sustainability refers to the equitable distribution of resources within and between generations in pursuing socioeconomic activities, given the bounded ecosystem (Stoddart, 2011). Bañon Gomis et al. (2011) refer to sustainability as a moral course of action by which people seek to avoid harmful impacts on the environment, society, and the economy to ensure a harmonious relationship with these spheres that leads to a prosperous life. That is, a coherent definition of sustainability should consider the dynamic alignment and equilibrium between these spheres (Gossling-Goidsmiths, 2018).

The sustainable accumulation of physical and financial capital, biodiversity and environmental quality, and the improvement of culture, education, health, and living standards, inter alia, are at the heart of the economic, environmental, and social models that constitute the goal of sustainable development (Mensah, 2019; Acemoglu and Robinson, 2012). One could say that sustainable development is the journey to the destination, which is sustainability (Diesendorf, 2000).

### 2.1.3. The Concept of Sustainable Development

The concept of sustainable development has attracted worldwide attention over the last two decades. It extends to cover a wide range of disciplines, which makes the concept open to a plethora of interpretations. These various interpretations generally lead to the question of what should be sustained, who should steer the process and how long it should last. Therefore, a rigorous and acceptable definition should encompass multiple disciplines, such as economics, ecology, politics, law, technology, etc. (Hall, 2000).

Although many definitions abound, the most popular is found in the Brundtland Commission's 1987 report, Our Common Future: 'Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). It includes two important notions: The first is needs which emphasises the importance of meeting substantial needs, especially for the poorest. The second is the notion of limitation, where present and future needs are limited by ecological capacity, available

technology, and social systems. In addition to incorporating environmental considerations into the development process, the definition stresses the importance of inter-and intra-generational equity (Mitchell, 1996).

In the years following the Brundtland Report, a plethora of definitions of the concept of sustainable development emerged, most of which were based on the fundamentals of the WCED definition (Dobson, 1996). Accordingly, sustainable development is widely understood as a socioeconomic system that satisfies people's needs and enables long-term progress towards prosperity and better living standards in harmony with ecological capacity (Klarin, 2018).

Jabreen (2004) provides a comprehensive understanding of the concept of sustainable development by providing several metaphors drawn from a multidisciplinary literature review. These include (i) the metaphor of the ethical paradox representing the ethical domain of the concept of sustainable development which attempts to reconcile the difference between sustainability in the sense of preserving the natural environment and development, which implies the constant use of natural resources; (ii) the metaphor of the natural capital stock illustrates the material perspective of the concept of sustainable development, e.g., renewable resources, non-renewable resources and the capacity of ecosystems to assimilate pollution caused by human activities (Roseland, 2000). In this regard, sustainable development means maintaining constant natural capital. Ecological economics widely adopt this view, which links economic systems to the ecosystem (Collados and Duane, 1999). (iii) the fairness metaphor reflects the social domain of the sustainable development concept and includes themes, such as democracy, empowerment, participation, and inter-and intra-generational equity in the distribution of resources and the balancing of social equity, economic and environmental goals; (iv) the eco-form metaphor is concerned with the spatial domain, i.e., urban space, of the concept of sustainable development. It deals with the sustainability of the built environment at different scales, e.g., buildings, villages, or cities; (v) the integrative management metaphor is the management perspective of the sustainable development concept, which strives for a holistic management approach that integrates social and economic development and environmental conservation to achieve sustainability; (vi) the metaphor of global discourse forms the political domain of the concept of sustainable development. It emerged from the global environmental discourse that globalised the national vision of sustainable development and created historical metaphors as

themes for global conferences, such as Earth Summit, World Summit, Our Common Future, Global Society, and so on; and (vii) the utopian metaphor which is the visionary realm of the concept of sustainable development. It describes an imaginary ideal community that is just, satisfies people's basic needs, and is in harmony with nature. Classical utopians, such as Fourier, Morris, Callenbach, and Kropotkin contributed to the literature on sustainable development by establishing a new ethic for the environment and criticising the prevailing development paradigm. Cabarino (1992), for example, points out that green policies, curbing population growth, and clean energy policies are the most important features of a sustainable society (Jabreen, 2004).

Lele (1991) argues that understanding the concept of sustainable development is closely related to environmental sustainability. More specifically, sustainable development is a process that improves the quality of life of present and future generations by ensuring an adequate state of the environment. The provision of such environmental conditions, in turn, requires a certain level of social sustainability in terms of well-being and social values, inter alia, which can influence environmental sustainability (Klarin, 2018). In this regard, the mainstream sustainable development theory assumes a long-term development orientation and encompasses social and environmental sustainability, where social change attains conventional development objectives in harmony with environmental limits (Lele, 1991).

Mitcham (1995) illustrates that sustainable development aims to equilibrate the need for development with the limits to growth. Vander-Merwe and Van-der-Merwe (1999) argue that sustainable development modifies the traditional economic development process to attain ecosystem integrity and improve quality of life. Similarly, Vare and Scott (2007) view sustainable development as a process that enhances human well-being through technological development, institutional cooperation, appropriate investment, and the accumulation of resources.

Unquestionably, the concept of sustainable development has been the subject of numerous debates and comprehensive investigations in various fields, resulting in a wide range of definitions and frameworks to conceptualise it (Murcott 1997). Therefore, all countries, irrespective of their economic system, i.e., laissez-faire, or centralised economy, and their level of development, ought to establish their economic and social development goals under the umbrella of sustainability. Table

2.1 provides an overview of the different definitions of the concept of sustainable development.

Table 2.1: Definitions of sustainable development.

| Author/Year | Definition |
|---|---|
| **Brundtland Report, WCED (1987)** | "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". |
| **Pearce et al. (1989)** | "Sustainable development implies a conceptual socio-economic system which ensures the sustainability of goals in the form of real income achievement and improvement of educational standards, health care and the overall quality of life." |
| **Meadows (1998)** | "Sustainable development is a social construction derived from the long-term evolution of a highly complex system – human population and economic development integrated into ecosystems and biochemical processes of the Earth." |
| **Vare and Scott (2007)** | "Sustainable development is a process of changes, where resources are raised, the direction of investments is determined, the development of technology is focused, and the work of different institutions is harmonised, thus the potential for achieving human needs and desires is increased as well." |
| **Martin et al. (2012)** | "Sustainability development refers to the ability of a society, ecosystem, or any such existing system to operate continuously in an undefined future without reaching key resource depletion." |

## 2.2. Conceptualising Sustainable Development

Following the above discussion, sustainable development became a cause celebre for researchers, policymakers, and international organisations, such as the United Nations, which introduced related agendas, platforms, and conventions (Atkinson, 2007). The International Institute for Sustainable Development (IISD) has identified five primary conceptual models of sustainable development, including partial models such as models that stem from economics and stress-response models, or complete models that incorporate the environment and human, namely multiple capital models, varying models of the three themes of social, economic and environment, and the linked human and ecosystem well-being model (Klarin, 2018).

In order to achieve the ultimate goal of sustainable development, namely, the long-run economic and environmental stability, the decision-making process should take into consideration the current economic, social, and environmental challenges (Disano, 2002). This integration involves a wide range of key actors in the economy

and government, such as industry, agriculture, universities, foundations, the health sector, and civil society organisations. On this basis, sustainable development is essentially built on three key pillars, namely economic development, environmental sustainability, and social inclusion. This model is called the "triple bottom line" and is the most common conceptualising of sustainable development (Elkington, 1998).

The three-pillar model (see Figure 2.1) has been criticised for failing to consider the interlinkages between the pillars and treating them as independent. Furthermore, it treats the pillars equally, allowing them to substitute each other (East and White, 2016). In contrast to the three-pillar model, the overlapping circles model (see Figure 2.2) takes into account the association of the sustainability dimensions and recognises that sustainable development takes place in the central part of the intersection of the circles. Assigning equal weights to the dimensions and acknowledging their independence is seen as a feebleness of this model (East and White, 2016). To address the shortcoming of the previous models, the nested circle model (see Figure 2.3) visualises the three dimensions as a system in which no dimension can be independent of another. In particular, the environment represents an incubator for the economy, which exists within society, implying that both the economy and society are limited by the natural environment (Anderson, 2012). This aligns with the concept of strong sustainability, where different capitals cannot be substituted.

Each model described above offers its own approach to conceptualising sustainable development, leading to different policy implications. However, the complex interlinkages between the dimensions of sustainability lead to practical challenges. The UK sustainable development charity, Forum for the Future, explains the concept by introducing the five capitals framework, which illustrates the available resources to society, including natural, human, social, manufactured, and financial capital. Maintaining these capitals is essential for sustainable development, and unequal investment in the different capital stocks can explain current environmental and social challenges (Parkin et al., 2003).

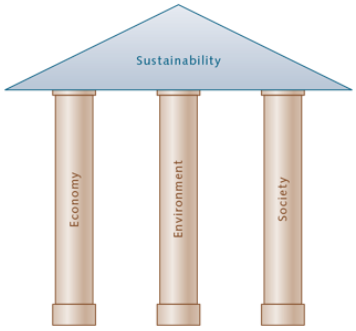



**Figure 2.1:** The three-pillar line model.

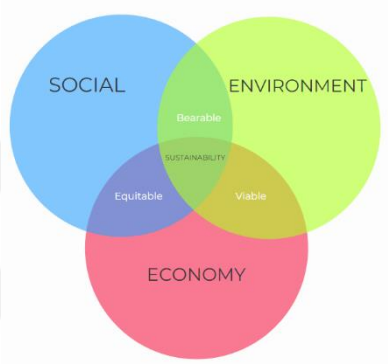



**Figure 2.2:** The overlapping circles model.

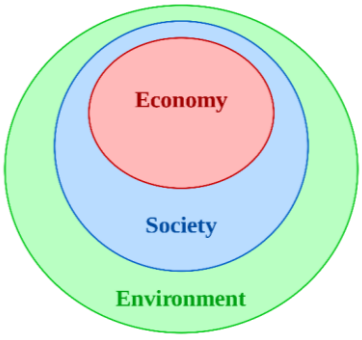



**Figure 2.3:** The nested circle model.

Ashford (2002) distinguishes between environmental policy and sustainable development planning agendas. The former follows coordinated policies to improve performance and reduce costs, control pollution, and ensure an adequate supply of skilled labour. Here, environmental policy can lead to narrowly-focused solutions that apply only to certain fundamental challenges. The latter, however, includes integrated policies targeting the economy and social systems. In specific, these policies aim to stimulate technological change in production, curb pollution and reduce the use of

non-renewable energy and devise modern socio-technical systems that promote employment (Ashford, 2002).

In essence, the complexity and interrelationships between the three dimensions of sustainability raise several challenges for governments and social organisations, which require smart policies that take a systematic approach to address these challenges (Hall, 2006). Specifically, the aggregate system that comprises and supports human society is made up of many subsystems, i.e., economic systems, environmental systems, and social systems. This system can only operate efficiently and sustainably if all other subsystems are functioning properly. Thus, to understand whether these systems are functioning appropriately, it is essential to identify the individual subsystems, establish theoretical definitions of these concepts and assign appropriate indicators to measure each system (Bossell, 1999).

### 2.2.1. Economic Sustainability

The notion of economic sustainability indicates a "system of production that meets present consumption levels without compromising future needs" (Basiago, 1998). Here, economic sustainability aims at the sustainability of the economic system itself. This concept first appeared in Hicks's (1939) definition of income in his book Value and Capital. While Hicks focuses on man-made capital, Goodland (1995) proposed to extend the definition to include natural, social, and human capital to accurately reflect economic sustainability.

Others define sustainable economic development as the ability to maintain constant production, stable debt, and sectoral balance in the economy (Harris, 2000). Wiebe (2012) denotes that realising a prosperous, innovative, competitive, knowledge-based, and eco-friendly economy is at the core of sustainable economic development that emphasises a qualitative enhancement of standards of living.

In contrast to traditional economists who assumed an unlimited supply of natural resources, Meadows et al. (1972) in The Limits to Growth assume that exponential growth of population and resource consumption will eventually lead to resource scarcity. Schumacher (1973), in Small is Beautiful, opines that mainstream economics harnesses nature and proposes an alternative view, "Buddhist economics", which is based on, inter alia, attaining given ends with minimum means. Others, such as Daly (1973), believe that environmental limits pose a significant

obstacle to economic growth and propose a steady-state economy to limit the physical scale of the economy. However, the growing popularity of neoliberal free-market economic theory in the 1980s, which advocates capitalist enterprise and economic growth, contradicts the earlier views (Giddens, 1994). Consequently, natural resources have been affected by the expansion of the economic system, requiring a redefinition of the assumptions of mainstream economics (Du and Kang, 2016; Basiago, 1998). In addition, economic growth driven by oil, debt, and technology is deemed to seize in the long run (Thomson, 2017).

In this regard, the accounting framework used to drive and assess the economy in its three main activities - production, distribution, and consumption - does not take into account distorted social and environmental values (Cao, 2017). Furthermore, Retchless and Brewer (2016) claim that economic growth has become the main concern of markets driven by high demand for goods and services, without taking into account other important costs, such as the impact on the environment. Achieving economic sustainability, therefore, requires an integrated approach that harnesses the prospective benefits of each of the key pillars of sustainability to achieve favourable economic growth while preserving the natural base.

### 2.2.2. Environmental Sustainability

The concept of environmental sustainability refers to maintaining the productivity and resilience of the natural environment, which is critical to human activities (Mensah, 2019). Ecological resilience is the ability of a system to maintain or regain its normal level after a shock or disturbance (Harris, 2000). Natural resources act both as suppliers of economic inputs, i.e., sources, and as absorbers, i.e., sinks, of economic outputs, i.e., wastes (Pearce and Redclift, 1988; Pearce et al., 1990; Goodland and Daly, 1996). This implies that maintaining the equilibrium of Earth systems requires a balance between the rates of harvesting and regeneration of natural capital, on the one hand, and the emission of wastes and their absorption into the environment, on the other (Khan, 1995; Goodland, 1995; Diesendorf, 2000).

Environmental sustainability encompasses ecosystem integrity, biodiversity, and carrying capacity (Brodhag and Taliere, 2006). This view differs from the economic perspective of sustainability, which focuses on consumption. Common and Perrings (1992) discern between these views by explaining how Solow sustainability and Holling sustainability diverge. The former is based on constant consumption

economic models, while the latter assumes ecosystem resilience. This suggests no close relationship exists between environmental sustainability and economic efficiency.

The pursuit of exponential growth is reaching the limits of ecosystems where technological development no longer allows unbridled growth (Ehrlich and Ehrlich, 1990). Essentially, nine planetary boundaries describe the ecosystem functions within which humans can safely conduct their activities, as Rockström et al. (2009) noted. These include climate change, ocean acidification, stratospheric ozone, the biogeochemical nitrogen cycle, the phosphorus cycle, global freshwater use, land system change, biodiversity loss as measured by atmospheric $CO_2$ concentration, aragonite concentration in seawater, $O_3$ concentration, $N_2$ levels, P influx into the oceans, freshwater use, Earth's ice-free area and the rate of species extinction per million species, respectively. They have also identified chemical pollution and atmospheric aerosol pollution without quantifying the thresholds for either.

According to the findings of Rockström et al. (2009), exponential growth and expansion of human activities have already pushed the limits of three planetary boundaries, namely climate change, the rate of biodiversity loss and changes in the global nitrogen cycle. Crossing one or more of these limits can disrupt the global environment and trigger irreversible changes. As a result, the Earth's system may lose its resilience and sustainability (Scheffer et al., 2009; Lélé, 1998). This means that humanity depends on the natural environment's productivity, robustness, and resilience, which is determined by spatial heterogeneity and functional diversity. These characteristics, in turn, form a reservoir of ecosystem services (Holling, 1973).

In light of the above, environmental resources should be allocated in a way that does not threaten the system or its subsystems, as suggested by the ecological-economic approach (Common and Perrings, 1992). And although there is a widespread misunderstanding about the meaning of sustainability that limits it exclusively to environmental sustainability, it is important to include market forces and inequality as they have a negative impact on the ecosystem. Thus, to achieve overall system sustainability, the ecosystem must be protected through sustainable consumption and production, which can be achieved through economic and social reforms (Basiago, 1998).

### 2.2.3. Social Sustainability

The concept of social sustainability is somewhat ambiguous, as it has undergone various interpretations due to its qualitative nature, multidisciplinary approach, multidimensional characteristics, dynamic nature, and context specificity (Littig and Griessler, 2005; Colantino, 2010; Ghahramanpouri et al., 2015; Dempsey et al., 2011). The concept first appeared in the Bruntland Commission report, which highlighted social challenges, such as health and income inequality (WCED, 1987). At its core, social sustainability is about human society. It aims to satisfy intrinsic human needs and ensure that the needs of future generations are met (Littig and Griessler, 2005). In other words, social sustainability means equity in the distribution of resources (Baffoe and Mutisya, 2015). Specifically, social sustainability encompasses cultural, social, and political aspects that include a plethora of notions, such as equity, participation, empowerment, cohesion, cultural diversity, gender issues, human rights, and stable institutions (Daly, 1992; Bostrom, 2012).

In a sense, social sustainability takes the perspective of the human development approach in traditional economic theory, which focuses on human needs and equity (Harris, 2000). In this sense, social sustainability is the capacity of social systems to improve well-being and alleviate poverty. It thus integrates physical and social systems, with physical infrastructure being important for social and cultural life (Woodcraft et al., 2011). Another definition relates the concept of social sustainability to the interaction between social conditions, such as poverty and environmental degradation (Ruttan, 1991). Correspondingly, social sustainability postulates that poverty alleviation must not compromise environmental quality or economic stability but must be achieved within the limits of society's environmental and economic resources (Scopelliti et al., 2018).

Spangenberg (2002) argues that both human capital, such as education, experience, etc., and the right to engage in social activities are at the heart of social sustainability. The ability to access physical, legal, and economic resources gives the right to participate in social activities. In this context, access to physical, legal, and economic resources requires the availability of technical, social, and institutional infrastructure, the right to use physical capital, and the affordability to use these capitals, respectively. Magis and Shinn (2009) establish principles for the concept of social sustainability, namely well-being, equity, and democracy. This means that

social sustainability varies greatly by context, as well-being priorities differ across societies.

### 2.3. The Interlinkages Between Sustainability Pillars

The previous sections have shown that preserving the environment, in conjunction with economic and social well-being for present and future generations, is a prerequisite for sustainability. The main pillars of sustainability, namely economic, environmental, and social, reflect how sound development should integrate the planet, people, and profits (Elkington 1997; Schoolman et al. 2012). However, approaches based on balancing the sustainability pillars have been criticised in the literature for several reasons. First, the pillars of sustainability include heterogeneous values that are not necessarily comparable, such as biodiversity, profits and equity, social diversity, and health (Hirsch Hadorn, 1999). Second, different stakeholders often have conflicting interests or preferences within each pillar of sustainability (Kyburz-Graber et al., 2006). Finally, the complexity of the interlinkages between anthropogenic activities and the ecosystem prevents an appropriate balance between the pillars of sustainability from being achieved (Kates et al., 2001).

Several conflicts and synergies between the pillars of sustainability can be identified as follows: 1. Economy-Environment: Economic and population growth lead to environmental degradation through higher consumption, energy use, deforestation, and greenhouse gas emissions (Teodorescu, 2012). However, higher economic growth can improve the environment through the income effect (e.g., individuals are willing to buy greener products and push for environmental-friendly legalisations), the technological effect (e.g., cleaner production through the introduction of new technologies and R&D spending), and the composition effect (e.g., the shift to service sectors and technology industries) (Grossman and Krueger, 1991). Investment is another mechanism that can influence this relationship, as investments in clean technologies and renewable energy sources improve the quality of the ecosystem. 2. Environmental-Economy: higher environmental quality and biodiversity trigger economic growth through, inter alia, higher productivity, sustainable tourism, and sustainable construction that conserves non-renewable resources, thus increasing economic savings (Waage et al., 2015; Gurung and Seeland, 2011; Vatalis et al., 2011). In addition, environmental policies in the form of pollution caps and eco-taxes

have the potential to optimise resource allocation and, thus, economic growth (Teodorescu, 2012).

3. Environment-Social: issues of environmental and social sustainability issues are interlinked, with natural capital and ecosystem services being essential for human health through providing access to water and energy, waste management, and reducing greenhouse gas emissions and, thus, global warming. Social equity through equal distribution and affordable energy services enhances inclusion and quality of life. In addition, the availability of environmental capital, such as energy, boosts economic sectors and, thus, productivity, employment, and development. 4. Social-Environment: social factors alter the surrounding natural environment. Poverty, illiteracy, exclusion, and rural vulnerability, for example, affect the environment by putting pressure on land, forests, and fisheries (Harris, 2000).

5. Economy-Social: economic growth increases productivity and provides more employment opportunities, leading to a higher standard of living. 6. Social-Economy: investment in human capital, i.e., in health, education, and well-being, and social inclusion, boosts the productivity of the economy.

In sum, adequate production, distribution, and consumption patterns are crucial for economic sustainability, while appropriate planning, halting biodiversity loss and protecting ecosystems represent important factors for environmental sustainability. Social sustainability is driven by the availability of human rights, health care, equal opportunities, quality of education, gender equality and quality of legislation. Clearly, the three pillars of sustainability have the concept of intergenerational equity in common, which ensures the needs of present and future generations. Sustainable development requires a systematic approach that integrates the pillars of sustainability, strives for mutually reinforcing outcomes, and minimises conflicting goals to simultaneously achieve economic, environmental, and social benefits. This requires the cooperation of international organisations, such as the UN, local governments, non-governmental organisations, and civil society organisations.

## 2.4. Sustainable Development Goals

The global challenges facing humanity today, such as rapid population growth, urbanisation, shrinking economies, climate change, pandemics, and democratic crises, are accelerating at an unprecedented pace. These ongoing trends are pushing the Earth beyond its natural limits while increasing the demand for resources, such as energy, water, and food. These challenges translate into the Millennium Development Goals (MDGs), which include eight goals covering several areas (UN, 2008). While the MDGs provided a springboard for the global sustainable development agenda (Breuer et al., 2019), there has been little progress towards achieving them. Therefore, in 2015, the UN introduced the Sustainable Development Goals (SDGs) to set a new roadmap for development combining the resolutions of the MDGs and Rio+ (Fukuda-Parr, 2016).

The UN 2030 Agenda, adopted by 193 UN member states, expanded the scope of the MDGs to include a comprehensive list of themes known as the five Ps, namely People, Planet, Prosperity, Partnerships, and Peace (Kanie and Biermann, 2017; Zhai and Chang, 2019). The SDGs comprise a collection of 17 core goals that span 169 targets, as well as 200 indicators that guide nations' strategies to implement these goals by 2030. The SDGs are a call to action for governments and have increased the depth of sustainability themes to include inter alia, ecosystems, climate change, energy, innovation, poverty, gender equality, peace, hunger, health, education, sustainable cities, and partnerships (Mantlana and Maoela, 2019; Kanie and Biermann, 2017).

The SDGs are designed to tackle the multi-faceted socio-economic and environmental problems by recognising their interdependencies and adopting a multidisciplinary, transdisciplinary, and integrated approach to solving them (Elder et al., 2016). In addition, the SDGs promote collaboration between governments, industry, academia, and civil society organisations to ensure appropriate solutions that can improve the quality of life of future generations (Breuer et al., 2019).

Essentially, each SDG is the outcome of a lengthy research and negotiation process between multiple stakeholders and governments (Tosun and Leininger, 2017; Loewe and Rippin, 2015). As a result, these goals may overlap and bring positive or negative feedback for different scales and contexts (Weitz et al., 2018). Thus, each SDG represents an essential piece of a holistic, interrelated, and complex puzzle (Kumar et al., 2014). On the one hand, the goals reinforce each other through

complementarity, e.g., addressing climate change can improve energy supply, health, and biodiversity (Le Blanc, 2015). On the other hand, the SDGs can also create tensions that require a balanced approach towards these goals. For instance, achieving food security threatens biodiversity through deforestation (Espey et al., 2015). SDGs can also be path-dependent, meaning that the implementation of one goal impacts another but not vice versa (McCollum et al., 2018; Nilsson et al., 2016). For example, the provision of efficient energy services requires the availability of sustainable infrastructure (Fankhauser et al., 2008). In contrast, implementing one goal does not necessarily lead to achieving another goal, such as infrastructure and nutrition (Gillespie and van den Bold, 2017).

Given these interconnections, policymakers have two options: a defensive approach or a proactive approach. The former takes a passive approach, where no specific policy is pursued, but firms continue to operate with the expectation that some targets will be arbitrarily achieved. Certainly, such an approach leads to incomprehensible and inefficient policies with adverse effects. The latter approach identifies critical issues and interdependencies and accordingly sets coherent policies to achieve key objectives in collaboration with stakeholders at national and regional levels (Breuer et al., 2019).

Against this background, several approaches have emerged to categorise the SDGs, map their linkages, and assess the nature of these relationships. These approaches differ in their methodology, context, scope, and policy implications. One approach is to systematically cluster the SDGs according to their outcomes, known as a doughnut (Raworth, 2012; Niestroy, 2016). These models attach great importance to securing basic human needs and input-output relationships for each SDG but fail to explain the causal relationships between the SDGs (Breuer et al., 2019). Other models, such as Le Blanc (2015), examine the relationships between the SDGs at the target level, which allows for a detailed analysis of the interlinkage but does not provide policy actions to address this complexity.

An alternative approach by Allen et al. (2018) addresses this backdrop by prioritising policy actions to implement the SDGs. Finally, numerous applied empirical analyses have emerged to examine the interactions between the SDGs, taking into account the existence of synergies and trade-offs that can improve policy coherence, such as simulation models, integrated assessment models, and cross-impact matrices (Griggs et al., 2014; Campagnolo et al., 2018; Collste et al., 2017; Nilsson

et al., 2016; Weitz et al., 2018; Pradhan et al., 2017). Although these different approaches offer a systematic analysis of SDG linkages, their practical application proves difficult due to methodological and contextual issues, as well as differences in the ranking of key goals, among other factors (Breuer et al., 2019).

It is important to note that different stakeholders have conflicting interests in relation to the SDGs, which in turn influences governance (Keitsch, 2018). To illustrate, fossil fuel companies can thwart efforts to address climate change (SDG 13) as they place greater importance on their short-term profits than on long-term benefits to society (Le Blanc, 2015; Tosun and Leininger, 2017). The availability of appropriate indicators and performance evaluation are crucial to ensure progress on the SDGs (Mohieldin, 2017). That is, appropriate input and output measurement enables governments to assess the effectiveness of their investments in addressing the challenges and achieving the goals and targets (Allen et al., 2018). Several scholars have investigated the protentional profit of implementing the SDGs, including inter alia, job creation, new business opportunities, energy efficiency, improved health care, and technological innovation (Schütze et al., 2017). Nevertheless, implementing the SDGs comes at a high cost and requires enormous financial resources. UNDP (2012) shows that tackling a problem like global warming can cost around $249 billion.

In summary, sustainable development is a multidimensional concept in terms of space, time, and the different perspectives of development itself. The SDGs are intended to provide a clear path for future development. However, the enumeration of debates on the interconnectedness, complexity, costs, and benefits of the SDGs, as well as the policy implications, have yet to be concluded hitherto. It is significant to approach sustainable development taking into account country-specific challenges, national capacities and policies, level of development and priority areas (Tosun and Leininger, 2017; O'Neill et al., 2018; Allen et al., 2018).

### 2.4.1. Urban Sustainability - SDG11

Urban sustainability can be traced back to the United Nations Conference on Human Settlements (Habitat I) in 1976 when governments began to realise the scale and consequences of rapid urbanisation. In parallel, the discussion on urban sustainability surged in academic research due to its crucial impact on urban prosperity. Yet, surprisingly, the definition of urban sustainability has been

complicated, multifaceted, and ununified hitherto (Bibri and Krogstie, 2017; McManus, 1998).

Most definitions of urban sustainability derive from definitions of sustainability that aim to promote long-term well-being by protecting the environment, using resources more efficiently, and improving social equity and justice (Huang et al., 2015). Camagni et al. (1998), Ratten (2017), and Tranos and Gertner (2012) emphasise that urban sustainability integrates environmental, social, and economic dimensions that promote urban innovation and sustainability by balancing economic development and urban regeneration, environmental protection and integration, and social equity and justice. To illustrate, economic productivity as the ultimate engine of growth is closely linked to healthy and educated citizens with access to basic needs, such as clean water, healthcare, sanitation, education, and electricity. This is where the role of cities lies in providing efficient infrastructure and green technologies, including improved transport, waste management systems, recycling, green buildings, etc., as well as fostering a diverse culture and innovation to improve their metabolism, attract a competent workforce and achieve inclusive growth.

While economic sustainability in the urban context focuses on creating long-term economic growth and prosperity, including wealth creation, productivity, quality jobs, and competitiveness (Pozdniakova, 2017), urban environmental sustainability aims to reduce pollution, minimise energy and material consumption, develop zero-waste systems and conserve natural resources (Bibri and Krogstie, 2017). Urban social sustainability, on the other hand, is a multi-faceted and broad concept that encompasses social inclusion and cohesion, intergenerational equity, human rights, and fairness (Dempsey et al., 2011).

Cities are embracing a circular economy model that uses more human capital than natural resources, eliminates waste and retains value added in the long term, allowing cities to move towards sustainable development (Ghisellini et al., 2016; Smol et al., 2017). This model reflects the interrelationships between the pillars of sustainability, where environmental sustainability means reducing the consumption of energy and natural capital and relying on renewables; economic sustainability denotes saving costs by reusing resources, increasing resource efficiency and value, and minimising the cost of environmental taxes and legislation; social sustainability is promoted by creating new employment opportunities due to the emergence of a green market and a stronger sense of community (Korhonen et al., 2018).

Wu (2014) defines urban sustainability as the process of creating and maintaining a virtuous cycle between ecological services and well-being by adopting economic, social, and environmental solutions to urban changes and challenges. Recently, it has become clear that cities play a prominent role in solving environmental problems and propelling progress in sustainable development (Hoornweg et al., 2011; Klopp and Petretta, 2017). Towards this end, the UN has included Goal 11 in its 2030 Agenda, which aims to *"make cities and human settlements inclusive, safe, resilient and sustainable"*. This goal specifically addresses urban sustainability and includes cross-cutting issues ranging from climate change to human rights. It also focuses on the importance of collaboration and inclusion of different actors and partnerships to improve urban sustainability (Brorström et al., 2018; Ferraris et al., 2018).

SDG 11 is considered an important tool for addressing urban challenges and developing mechanisms tailored to specific urban contexts to promote sustainable and inclusive cities. It is important to note that SDG 11 is linked to several other SDGs, including SDG 3 (health and well-being), SDG 5 (gender equality), SDG 6 (clean water and sanitation), SDG 10 (reducing inequalities), SDG 12 (responsible consumption and production) and SDG 13 (climate action). SDG 11 impacts each of these SDGs by advocating for healthy lifestyles, enhancing urban design and safety, improving resilience to natural disasters, prioritizing marginalized groups, and facilitating a cost-effective and sustainable transportation system that curtails emissions.

Summarising, promoting a sustainable urban environment requires an integrated approach to urban governance that fosters the relationship between citizens and their surrounding environment, enabling a better quality of life and green businesses that provide long-term economic prosperity. Specifically, policymakers should identify opportunities and challenges by assessing policies, socio-economic factors and processes that affect the metabolism of the city to formulate sustainability goals (Disano, 2001). Table 2.2 provides an overview of the urban sustainability's definitions.

**Table 2.2:** Definitions of the concept of urban sustainability.

| Author/Year | Definition |
|---|---|
| **Newman and Jennings (2012)** | "Ecosystems which are ethical, effective (healthy and equitable), zero-waste generating, self-regulating, resilient, self-renewing, flexible, psychologically fulfilling and cooperative." |
| **Munier et al. (2007)** | "A sustainable city is one in which the community has agreed on a set of sustainability principles and has further agreed to pursue their attainment." |
| **Camagni (1998)** | "Sustainable urban development is a process of synergetic integration and co-evolution among the great subsystems making up a city (economic, social, physical and environmental), which guarantees the local population a non-decreasing level of wellbeing in the long term, without compromising the possibilities of development of surrounding areas and contributing by this towards reducing the harmful effects of development on the biosphere." |
| **Hamilton et al. (2002)** | "The process of developing a built environment that meets people's needs whilst avoiding unacceptable social or environmental impacts." |
| **Wu (2014)** | "An adaptive process of facilitating and maintaining a virtual cycle between ecosystem services and human well-being through concerted ecological, economic, and social actions in response to changes within and beyond the urban landscape." |

## 2.5. SMART CITIES VS SUSTAINABLE CITIES

The need for global change arises not only from an environmental perspective but also from economic and social challenges, as well as governance and transparency issues (Escamilla Solano et al., 2017). Thereby, the concept of a sustainable city emerged in the 1990s, highlighting the interrelationships between economic, social, and environmental aspects of sustainability (Roy, 2009). A sustainable city can be understood as an urban form designed to improve environmental quality and social equity by adopting sustainable development strategies that boost innovation in urban systems, i.e., built infrastructure, ecosystems and human services and management (Bibri and Krogstie, 2017). Specifically, sustainable cities improve the efficiency of urban metabolism (Kennedy et al., 2007) by aiming for a zero-waste system and net-zero emissions, using renewable energy and maximising resource and transport efficiency. This means that themes, such as green economy, sustainable buildings and mobility, environmental justice, resource management, and renewable energy are features of sustainable cities (Dizdaroglu, 2015; Jabareen, 2006; Stossel et al., 2015; Wolch et al., 2014).

By the same token, smart urban technologies have come to the fore in the last decade as a promising response to the challenge of urban sustainability. Towards this end, smart cities use ICTs as a strategic tool alongside social and environmental

capital to enhance urban competitiveness (Schaffers et al., 2012). Smart cities encompass areas, such as smart buildings, intelligent transport systems, smart resource management, smart economy, etc. This development has eclipsed the ideology of sustainability and has become the blueprint for planning and managing cities (Dizdaroglu and Yigitcanlar, 2016).

Many authors, such as Gazzola et al. (2019) and Bifulcoet al. (2016), argue that while smart and sustainable cities share a common vision vis-à-vis sustainability, the path toward green or smart cities would lead to different solutions and path-specific challenges that could slow down or hinder progress towards substantiality (See Table 8 for the sustainability-oriented definitions of the smart city). Thus, it is important to understand the link between the two concepts to understand their rationale and design concepts (Visvizi et al., 2018; Bifulcoet al., 2016).

Höjer and Wangel (2015) and Kramers et al. (2014) claim that the smart city concept only vaguely associates smart solutions with sustainability and pays little attention to environmental concerns. De Jong et al. (2015) state that the smart city vision associates green concepts with green spaces instead of considering the actual environmental issues. Bibri and Krogstie (2017) note that sustainable cities focus on design concepts and principles and neglect smart solutions, while smart cities embrace ICT and ignore design aspects.

Ahvenniemi et al. (2017) distinguish the assessment frameworks of smart and sustainable cities to investigate the similarities and differences between the two concepts. The authors found that smart cities tend to focus more on social and economic sustainability but include few indicators of environmental sustainability. In contrast, sustainable cities cover environmental aspects comprehensively but leave out social aspects (Bibri and Krogstie, 2016; Jabareen, 2006). In fact, Ahvenniemi et al. (2017) claim that technology should enable sustainability rather than being an end in itself. Consequently, "a city that is not sustainable is not really smart". Further, the smart city is tailored to a specific context where strategies require the input of local stakeholders to develop short-term actions, as opposed to sustainability which takes a global approach (Correia et al., 2020).

That is, smart cities are characterised by short-term profits, are profit-driven, business-friendly, carbon-focused, elitist, and materialistic. In contrast, sustainable cities focus on long-term outcomes and are equilibrium-oriented, environmentally friendly, carbon neutral economy, inclusive and de-materialistic (Yigitcanlar et al.,

2019). Clearly, both smart and sustainable cities aim to create a better quality of life and balance economic growth with environmental concerns. On the one hand, sustainable cities focus on public policy design and soft measures, such as promoting the use of renewable energy to protect the urban environment (e.g., Leyden, 2003). On the other hand, smart cities rely on modern technologies and citizens to address these issues, with smart devices monitoring urban performance and influencing new lifestyles and behaviours in terms of energy consumption, transport choices, etc. In this context, this technocratic approach to the smart city would lead to a lack of awareness of the risks associated with investing in technologies and a deviation from their goals (Gazzola et al., 2019).

**Table 2.3:** Sustainability-oriented definitions of smart city.

| Author/Year | Definition |
|---|---|
| **Bakici et al. (2010)** | "Sustainable, greener, highly technological city with competitive and innovative commerce, and an enhanced quality of life that creates connections between people, information and urban elements, through the use of new technologies." |
| **Caragliu et al. (2011)** | "A city that is smart when investments in human and social capital and traditional transport and modern ICT infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." |
| **Thuzar (2011)** | "Smart cities are cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals." |
| **Barrionuevo et al. (2012)** | "Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centres that are at once integrated, habitable and sustainable." |
| **Kourtit and Nijkamp (2012)** | "Smart cities derive from knowledge-intensive creative strategies that have as a goal the improvement of the socioeconomic, ecological, logistic and competitive performance of cities and rely on a mixture of human, infrastructural, social and entrepreneurial capital." |
| **Zygiaris (2013)** | "A smart city is a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth that lead to smart city conceptions as "green" referring to urban infrastructure for environment protection and reduction of $CO_2$ emission, "interconnected" related to the revolution of broadband economy, "intelligent" declaring the capacity to produce added value information from the processing of city's real-time data from sensors and activators, whereas the terms "innovating", "knowledge" cities interchangeably refer to the city's ability to raise innovation based on knowledgeable and creative human capital." |

## 2.6. The Impact Of Smart City Drivers On Urban Sustainability

Contemporary debates in urban and academic circles continue to focus on the role of smart cities in promoting urban sustainability. Proponents claim that smart cities facilitate sustainable development by utilising innovative solutions and opportunities to manage cities efficiently, improve energy efficiency and the built environment, enhance the quality of life, and protect the natural environment (Hollands, 2008; Angelidou, 2014; Viitanen and Kingston, 2014; Bifulco et al., 2016, Cowley and Caprotti, 2019; Thellufsen et al., 2020). This vision is reflected in smart city policies around the world, such as the European Commission's smart city policy and technology giants (Haarstad, 2016; Russo et al., 2016). Yet, there is limited evidence on whether smart cities can deliver urban sustainability (Gargiulo Morelli et al., 2013; Ahvenniemi et al., 2017; Alizadeh, 2017; Yigitcanlar and Kamruzzaman, 2018; Basiri et al., 2017).

Opponents, on the other hand, argue that smart cities and digitalisation do not meet the challenges of sustainability (Colldahl et al., 2013; Gabrys, 2014; Yigitcanlar and Teriman, 2014; Glasmeier and Christopherson, 2015; Shelton et al., 2015; Martin et al., 2018). The reasons for this are manifold. First, critics argue that smart city agendas are driven by large technology and engineering firms with the primary goal of increasing profits (Haarstad, 2016). That is, smart cities base economic growth as the ultimate objective of urban development rather than environmental or social sustainability (Alizadeh, 2017; Wiig, 2015; March et al., 2016; Söderström et al., 2020). Growth is achieved through digital innovations that open up new markets and foster a consumerist culture (March et al., 2016; Viitanen and Kingston, 2014).

Further, technology firms, investors in the digital economy and highly skilled workers are the main beneficiaries of the financial gains from economic growth, which increases economic inequality (Piketty, 2014; Söderström et al., 2020). In the process, smart cities are used for branding purposes to market digital products, maintain corporate power and expand social control. This dynamic creates clear tensions between smart cities and urban sustainability.

Secondly, critics claim that the mainstay of smart cities, technology, creates a digital divide that excludes citizens and hinders social equity. In specific, the benefits of digitalisation are unequally distributed among citizens and favour the wealthy (Glasmeier and Christopherson, 2015; Mcneill, 2016). Moreover, the success of smart city initiatives depends on citizen participation in urban governance through digital

platforms that turn citizens into instruments and data sources, raising questions about privacy and security (Gabrys, 2014; Colldahl et al., 2013). Moreover, the smart city vision glorifies technology, in specific, data-driven urbanism can promote discrimination, bias and malicious practices and support a particular political orientation (Janssen and Kuk, 2016). De Jong et al. (2015) argue that citizens' overuse of technology can lead to a disruption of their relationships with their surroundings.

Third, from an ecological perspective, the ubiquity of computing and the extensive use of ICTs in urban systems pose significant and multidimensional threats to the environment (Greenfield, 2013; Hollands, 2008; Bibri and Krogstie, 2016). And even though smart city applications are designed to improve energy efficiency, other applications, such as digital currencies, fuel energy consumption by mining crypto coins (Fadeyi et al., 2019). In addition, e-waste will represent new challenges as only 1 to 2 % of smart devices are recycled globally (Manhart, 2011).

Further, the growth associated with smart cities continues to increase the demand for resources in contrast to the purported green benefits of digital technologies. Viitanen and Kingston (2014) argue that proponents of smart cities overstate the potential benefits of digitalisation in decoupling economic growth from resource use and pollution. In some ways, technology can increase efficiency and optimise infrastructure. Yet claims that these efficiencies will improve the environment have been criticised as a form of greenwashing or corporate promotion of technology solutions to create new markets (Gabrys, 2014; Viitanen and Kingston, 2014; Yigitcanlar and Lee, 2014).

In addition, the complexity of the socio-cultural and environmental context of the urban environment requires meticulous planning of ICT solutions. Otherwise, they will have negative impacts in terms of increased energy consumption, given the embeddedness of ICT in economic, institutional, political, and social factors (Bibri and Krogstie, 2017; Hilty et al., 2006). Table 9 provides the smart city drivers' potential positive and negative impacts on urban sustainability.

**Table 2.4:** Summary of the positive and negative impact of urban smartness on sustainability.

| Sustainability | Driver | + Impact on sustainability | - Impact on sustainability |
|---|---|---|---|
| **Economic** | Technology | Productivity growth and efficiency (Manitiu and Pedrini, 2016). | |
| | | Higher employment (Allam and Newman, 2018). | |
| | | Economic growth (Stanley et al., 2018). | |
| | Community | TFP growth through knowledge spillovers and job search externalities (Lucas, 1988; Acemoglu, 1996; Jones, 2014). | |
| | | Transition to a knowledge-based economy (Collet et al., 2015). | |
| | Governance | Productivity growth by eliminating market imperfections and improving capital accumulation and financial inclusion (Kpodar and Andrianaivo, 2011; Faid et al., 2020). | |
| | Innovative economy | Cumulative R&D increases the stock of knowledge, increasing the economy's productivity level (Romer, 1990; Grossman and Helpman, 1991). | |
| | | Increase productivity through creative destruction, where new businesses replace existing ones and translate their innovations into technological change (Schumpeter, 1934; Aghion and Howitt, 1990). | |

| | | | |
|---|---|---|---|
| | Technology | Improved energy efficiency (Appio et al., 2019). | Increased production and e-waste disposal (Houghton, 2015). |
| | Community | Higher environmental awareness among citizens leads local governments to adopt green policies as well as to change energy consumption patterns toward more efficient resources (Grossman and Krueger, 1991; Mahalik et al., 2021). | Higher mobile subscriptions contribute significantly to the overall carbon footprint (Fehske et al., 2011). |
| **Environment** | Governance | Well-functioning institutions can improve environmental quality by implementing pollution control strategies, setting environmental policies, investing in renewable energy, expanding green spaces, and using fiscal transfers to support municipal waste collection and treatment (Wu, 2017; Polzin et al., 2015; Fors et al., 2015). | |
| | Innovative economy | Applications, such as e-banking and e-commerce allow online transactions instead of physical mobility (Carrillo et al., 2014). | |
| | | Promote the development of renewable energy, green technologies, and waste treatment processes (Gan and Smith, 2011; Miremadi et al., 2019; Liu et al., 2020). | |
| **Social** | Technology | Integrating technologies, such as nanotechnology into healthcare | Increase inequalities and |

| | | | |
|---|---|---|---|
| | | improves existing processes, diagnoses, treatments, efficiency, and thus life expectancy (Varkey and Athyal, 2005). | promote the digital divide (Van Winden and de Carvalho, 2017). |
| | | ICT platforms can significantly reduce crime rates and increase public safety (Mendonça et al., 2016). | Hacking, viruses, invasion of privacy, and theft of personal data (Galdon-Clavell, 2013). |
| | | ICT applications enhance the quality of life (Griffinger et al., 2007). | |
| | Community | Citizens in smart communities are more engaged in their communities and respect social values (Creed et al.,2001; Billings et al., 2014). | Citizens unable to take advantage of available technologies lag behind, which widens the income gap (Dabla-Norris et al., 2015). |
| | | Smart community have skills and information about potential incidents that improve their health (Pappa et al., 2009). | Exacerbates income inequality initially through changing labour composition and increasing the skilled labour 'composition effect' (Gregorio and Lee, 2002). |

| | | |
|---|---|---|
| | Promotes practices to combat discrimination and social exclusion (UNESCO, 2016). | |
| | Suppress inequality due to increased supply of educated people lowering wage premium for skilled employees 'wage compression' (Gregorio and Lee, 2002). | |
| | Services through e-government promote citizen participation through e-participation (Kudo, 2008; Srivastava and Teo, 2010). | Data collection, constant surveillance, and networking of urban systems under central control affect democracy and freedom of speech (Vanolo, 2016). |
| Governance | Reduces digital divide by employing fiscal policies, such as providing tax incentives and subsidies to encourage private sector donation of ICT equipment and expanding broadband networks in cities, and providing community ICT training (Cullen, 2001). | |
| | Addressing privacy issues by enacting privacy regulations and laws (Chang et al., 2018). | |
| | Effective government is vital to reducing income inequality through fiscal redistribution in income taxes | |

| | | |
|---|---|---|
| | and social transfers (Chong and Calderon, 2000). | |
| Innovative economy | | Increases income disparity by creating jobs for high-skilled employees (Breau et al., 2014) and generating capital gains for innovators (Aghion et al., 2019). |

### 2.7. Governance Of Smart City

Planning smart cities as complex systems with sustainability in mind requires a systematic approach to modelling smart cities as a critical strategy encompassing multiple domains and stakeholders. Indeed, developing a smart city requires that urban policy and governance be placed at its core (Yigitcanlar et al., 2019). Hence, we adopt the theoretical framework developed by Akan et al. (2021, 2018, 2022a, 2022b), in which systemic governance, institutional fragmentation, and positive and negative complementarity are applied to the analysis of smart governance in smart cities.

Akan (2018, 2022a, 2022b) and Akan et al. (2021) have introduced two modes of governance to explore the institutional roots of success and failure in the growth and development of developed and developing countries and to examine the relationship between the financial sector and macroeconomic governance and between renewable energy and climate change, respectively. The concept of complementarity can be defined as the achievement of better outcomes by two or more institutions when they mutually coexist rather than work separately (Hall and Soskice, 2001). However, Akan (2018) acknowledges the limitation of Hall and Soskice's (2001) definition, which only encompasses the positive depiction of complementarity, while in fact, the scope of complementarity goes beyond positive

complementarity and can be negative or positive complementarity in the form of synergy.

Hence, Akan (2018) provides a revised definition of complementarity as conceived by Hall and Soskice (2001), arguing that systemic analysis requires that complementarity be understood as the *"mutual reinforcement of a certain group of institutions in part or all of a social structure that improves or worsens clustering relative to alternative configurations"* (Akan, 2018; Hall and Soskice, 2001). Here, complementarity is divided into positive and negative complementarity. The former indicates that the system tends to perform better than alternative arrangements, and the latter performs worse than alternative arrangements.

### 2.7.1. Smart Complementarity

The concept of complementarity is used in many research areas, from macroeconomics to microeconomics and public policy (Franzese, 2001; Milgrom and Roberts, 1995; Den Boer, 2002). It is worth noting that the concept of complementarity is introduced for the first time in this research in the field of the smart city by applying Akan et al. (2021, 2018, 2022a, 2022b) framework to the smart governance of smart cities. Accordingly, the notion of complementarity is operationalised in relation to the smart city drivers to explain whether there are synergies between the drivers that could promote sustainability in the city.

The concept of "smart complementarity" is introduced as a type of positive complementarity where drivers work synergistically to improve sustainability. Four types of relationships can be identified between the drivers of the smart city and urban sustainability: (i) a 'smart' complementary relationship to improve sustainability, (ii) a 'negative complementary relationship to worsen sustainability, (iii) the combination of the first two options, and (iv) the absence of any relationship.

First, smart (positive) complementarities between technology, community, innovative economy and governance in the smartness-environmental sustainability nexus can arise as follows. Well-functioning institutions can improve environmental quality by implementing pollution control strategies, setting environmental policies, investing in renewable energy, expanding green spaces, providing tax incentives to promote corporate green innovation, and using fiscal transfers to support municipal waste collection and treatment (Wu, 2017; Polzin et al., 2015; Fors et al., 2015). Green R&D investments and eco-innovation, in turn, increase productive capacity by

replacing production with environmentally friendly resources (Cole et al., 2005; Lee and Min, 2015) and promoting the development of renewable energy, green technologies and waste treatment processes (Gan and Smith, 2011; Miremadi et al., 2019, Liu et al., 2020). Green technologies and ICT solutions improve energy efficiency (Chourabi, 2012; Chavan and Chavan, 2019) and achieve targeted environmental governance through real-time monitoring of the entire city.

The use of technology facilitates applications, such as e-commerce and e-banking that enable remote working and online transactions instead of physical mobility, resulting in less traffic congestion, lower energy consumption and less waste, i.e., less travel time and printed marketing materials (Romm, 2002; Coroama et al., 2015). At the same time, internet use enables higher levels of education and stimulates civic participation. Well-educated communities have higher environmental awareness and a preference for greener products. They also push local governments to take environmentally friendly measures and shift energy consumption patterns to more efficient resources (Mahalik et al., 2021).

In contrast, negative complementarities between technology, community, innovative economy and governance in smartness- environmental sustainability nexus may develop as follows. There may be a lack of active citizen participation, political interest in adapting ICTs to environmental sustainability, and insufficient incentives to promote green production. In parallel, extreme and exclusive reliance on technology and the implementation of black-box technology solutions due to the absence of appropriate policies that support sustainable ICT solutions. These ad-hoc implementations of technologies require increased use of production factors, including natural resources, leading to over-exploitation and over-use of natural resources (Li et al., 2021). In addition, the rapid growth of internet penetration increased electricity consumption, and e-waste disposal threatens environmental sustainability (Houghton, 2015).

Second, effective government stimulates R&D investment in private and public firms by supporting and subsidising innovation processes (Alam et al., 2019), incentivising efficient resource use and technological advances to increase productivity (Olson et al., 2000), improves the business environment by reducing bureaucracy and ensuring sound regulation (Çule and Fulton, 2013), increases labour market flexibility by improving administrative capacity and regulatory quality (Knack, 1999), and provides effective policies to promote education (Rajkumar and Swaroop,

2008). Similarly, e-governance integration supports productivity growth by addressing market imperfections and improving capital accumulation and financial inclusion (Kpodar and Andrianaivo, 2011; Faid et al., 2020). In addition, it increases the ease of doing business by reducing bureaucratic procedures, such as licencing and property registration (Martins and Viega, 2018), facilitating new business creation and entrepreneurial activities (Schnoll, 2015; Besley, 2015).

As a result of government public spending on education, the highly educated community builds the necessary knowledge that fosters entrepreneurial activities (Bodman and Le, 2013) and plays an important role in the transition to a knowledge-based economy, which increases employment in knowledge-intensive sectors (Collet et al., 2015) and facilitates the transition of workers between different sectors, improving labour market flexibility. The integration of ICT into production processes and the transformation into an innovative economy increase the stock of knowledge, which in turn increases the productivity and growth of the economy by integrating new technologies into the production process. This creates smart (positive) complementarities between the drivers of the smart city and economic sustainability.

However, these relationships can also occur in reverse, creating negative complementarities between smart city drivers and economic sustainability. Here, government policies lack sufficient support for digitalisation, entrepreneurship, education or subsidiaries to build innovative capacity. The resulting decline in educational attainment and skills of the population, as well as in the innovation capacity of the economy, can lead to a decline in investment and productivity, as well as a reversion to old production methods, ultimately stalling economic growth.

Third, smart (positive) complementarities can emerge between smart city drivers in the smartness-social sustainability nexus. Effective government plays a vital role in improving education and health through efficient public spending (Hauner and Kyobe, 2010), introduces e-government to respond to citizens' needs and provide public services online, and reduces the digital divide through the use of fiscal policies, such as the provision of tax incentives and subsidies to encourage the private sector to donate ICT equipment, the expansion of broadband networks in cities; community ICT training (Cullen, 2001) and reduces income inequality through fiscal redistribution in income taxes and social transfers (Chong and Calderon, 2000). At the same time, ICT applications in various areas improve citizens' health, mobility and overall quality of life. Similarly, improved education and higher digital skills lead to a smarter

population that is more engaged in its community and respects social values (Billings et al., 2014), has higher labour market participation and promotes practices to combat discrimination and social exclusion, all of which improve social sustainability. Moreover, economic growth resulting from R&D spending and technological progress opens up new employment opportunities and improves the quality of life.

Conversely, inadequate government policies regarding, inter alia, public services, digital inclusion, education and ICT policies can have a significant negative impact on social sustainability. In parallel, unequal access to ICTs or a lack of skilled labour can exacerbate inequality, which worsens social sustainability (Hargittai, 2003; Richmond and Triplett, 2018). This triggers negative complementarities between the drivers of the smart city in the nexus of smartness and social sustainability.

The presence of smart and negative complementarities, or their combination, leads to a complex set of policy choices and outcomes (Warford et al., 1997) that require appropriate governance of those choices and outcomes. To this end, the study introduces two modes of governance, systemic governance and fragmentation, to explain the nexus between urban smartness and sustainability. The importance of this concept is based on the fact that the joint complementary impacts, rather than the separate impacts per se, determine the overall level of sustainability (Akan et al., 2022).

### 2.7.2. Systemic Governance of Smart Complementarities

Based on the presence or absence of positive or negative complementarity, governance can be divided into systemic and fragmented governance. The first, systemic governance, refers to the process of managing the current and future complexity of micro-macro positive and negative complementarities through decision-making, regulation and monitoring to create and maintain institutional coherence (Akan, 2018). The second, institutional fragmentation, derives from a lack of systemic governance and implies a partial or absence of complementarity between decision-making processes, institutions and policies of the government and alternative bodies (Akan, 2018).

It is important to understand the term governance, defined as the "means by which to infuse *order,* thereby mitigate *conflict* and realise *mutual gain*" (Williamson, 2013). Building on this definition, smart city governance can be illustrated as the means of creating a regulatory environment (order) that enables actors to mitigate or

minimise the challenges of the city (conflict), thus enabling smart and sustainable pathways for all (mutual gain).

By the same token, we define systemic governance as a mode of governance that seeks to manage the smart and negative complementarities of the nexus between smartness and sustainability to establish and sustain institutional coherence. In other words, systemic governance implies mutual reinforcement between smart city drivers in improving or degrading urban sustainability. Thereby, urban sustainability depends, ceteris paribus, on appropriate systemic governance of smart city drivers, e.g., on the *"convergence of key policy choices"*, where urban sustainability is based on three pillars, namely economic, environmental, and social.

### 2.7.3. Fragmented Governance of Smart City

The failure of systemic governance to coordinate smart city drivers to achieve sustainability simultaneously is referred to as fragmented governance (institutional fragmentation). In this context, fragmentation can result from incoherent and contradictory objectives, inadequate implementation or addressing other issues. Thus, smart governance systemically combines and transforms the different fragments into a complementary cluster of beneficial co-existence.

Recent studies propose that smart city development has been fragmented, perplexing and an ad hoc approach to sustainability (Ahvenniemi et al., 2017; Bibri and Krogstie, 2017; Anthopolous, 2017). In specific, digital technologies should complement traditional development tools. In this regard, we argue that a systemic governance mode based on smart complementarity and institutional fragmentation in managing smart city drivers can increase or decrease urban sustainability, respectively. Thus, achieving a sustainable urban environment requires systemic governance of smart complementarities of technology, people, innovative economy, and policy.

## 2.8. A Conceptual Framework For Investigating The Relationship Between Smart City Drivers And Urban Sustainability

The lack of system-thinking in conceptualising smart cities, as well as the enormous complexities in managing ICT prevent smart cities from addressing environmental and socioeconomic issues (Bibri, 2018; Yigitcanlar et al., 2019; Colding et al., 2020).

In light of the discussion in the previous section, an increasing number of scholars are calling for further investigation into the contribution of smart cities to urban sustainability (Haarstad, 2016; Ahvenniemi et al., 2017; Bibri and Krogstie, 2017; Colding and Barthel, 2017; Trindade et al., 2017; Macke et al., 2018; Yigitcanlar and Kamruzzaman 2018; Toli and Murtagh, 2020). A summary of the previous studies on smart cities and urban sustainability is presented in Table 2.5. One strand of research focuses on identifying the concerns of sustainability within the concept of smart cities, contrasting the existing models and approaches to smart and sustainable cities and investigating whether cities can become smart without being sustainable or whether going smart converges or diverges from the path towards sustainability (de Jong et al., 2015; Colding et al., 2018; Bibri and Krogstie 2017; Yigitcanlar et al., 2018; Gazzola et al., 2019; Toli and Murtagh, 2020; Ahvenniemi et al., 2016). For instance, Bibri and Krogstie (2017) found that the concept of the smart city lacks a clear sustainability framework. This creates a critical gap in how to link sustainability policy with the technical requirements of smart cities to achieve urban sustainability.

Another strand of research attempts to empirically investigate how smart city initiatives can contribute to urban sustainability. For instance, Yigitcanlar and Kamruzzaman (2018) examined the impact of smart cities on sustainable urban development in the UK using panel data analysis. However, the author considered environmental sustainability without taking into account other aspects of sustainability. Moreover, Girardi and Temporelli (2017) developed a methodology called “smartainability” to estimate how far Italian smart cities are sustainable in economic, environmental, social and energy fields. Their analysis though was limited to smart projects in which smartness was evaluated based on technological solutions without considering other dimensions of smartness. Figure 2.4 illustrates the third research framework of the interlinkages between smart city drivers and urban sustainability.

**Table 2.5:** Summary of the previous studies on smart cities and urban sustainability.

| Author | Country/City | Aim | Research Design | Results |
|---|---|---|---|---|
| Wang and Zhou (2022) | China | The dynamic relationship between smart city implementation and urban sustainability | PVAR | Urban smartness and sustainability have achieved coordinated development. |
| Fan et al. (2021) | China | The impact of smart city policy (SCP) on urban low-carbon economic development (LCE) | Data envelopment analysis (DEA) and differences-in-difference analysis (DID) | Results show that the implementation of SCP can significantly improve the LCE of cities. |
| Nicolas et al. (2020) | 50 smart cities | The direct and indirect effects of smart city enablers on urban performances | SEM | Both non-technical enablers and technical drivers have significant impacts on the performances of smart cities. |
| Yigitcanlar and Kamruzzaman (2018) | 15 UK cities | The changes in $Co_2$ due to smart city policies | Panel data analysis | The link between city smartness and $Co_2$ is not linear, and the impact of city smartness on $Co_2$ does not change over time. This finding calls for better aligning smart city strategies to lead to concrete sustainable outcomes. |
| Angelidou et al. (2017) | 32 applications addressing environmental sustainability issues | The potential contribution of smart city approaches and tools to sustainable urban development in the environment domain | Qualitative analysis | Smart and sustainable city landscape is extremely fragmented both on the policy and the technical levels. |

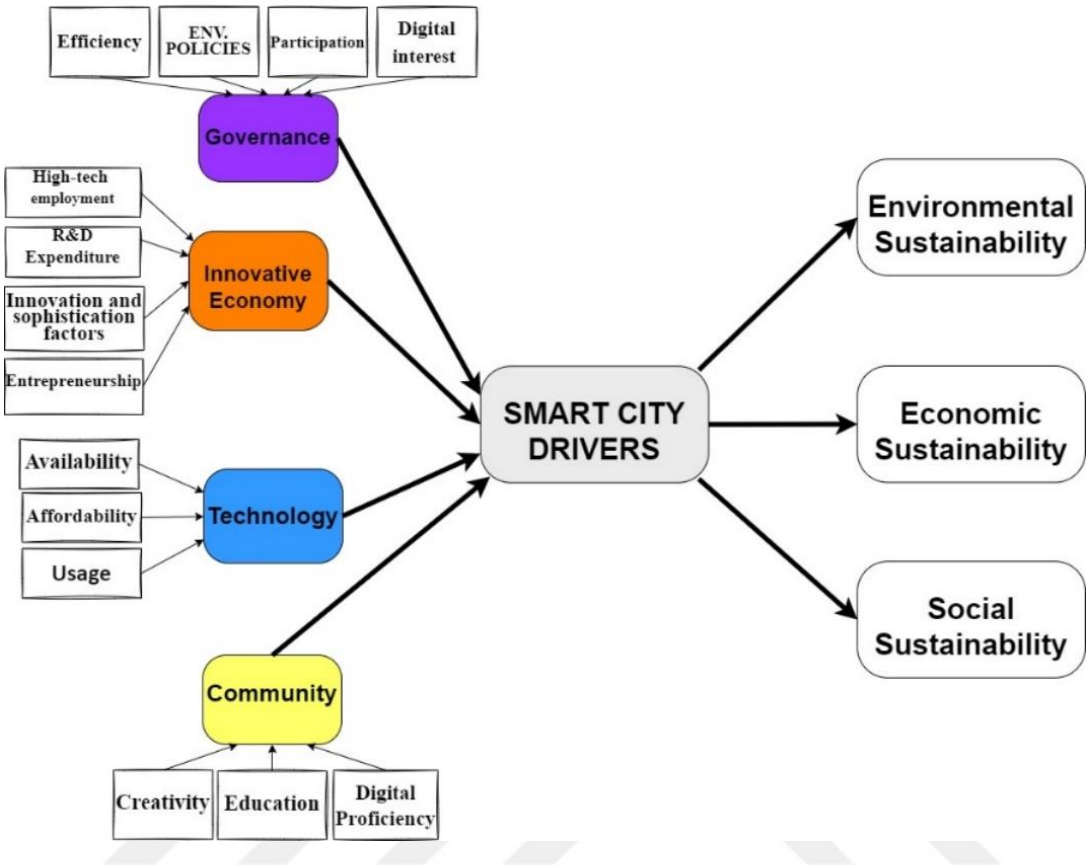



**Figure 2.4:** The research third framework.

# CHAPTER THREE
# RESEARCH METHODOLOGY

## 3.1. Research Objectives, Questions And Hypotheses

This research aims to explore the impact of smart city implementation on urban sustainability. The specific objectives are:

RO1: Map the interlinkages among the smart city drivers, outcomes, and negative externalities.

RO2: Develop a static and dynamic index for smart cities.

RO3: Investigate the impact of smart city drivers and urban sustainability.

A set of research questions were developed by reviewing the existing literature to guide the research. Hence, the research study sought to collect data to answer and examine the following research questions:

RO1- What are the synergies and trade-offs between the smart city indicators?

RQ2- How did the ranking of smart cities evolve from 2005 to 2019?

RQ3- Can the systemic governance of smart complementarities achieve urban sustainability?

The hypothesis related to RQ3 to be tested are:

$H_1$: There is a significant positive causal relationship between systemic governance of smart complementarities and smart sustainability.

$H_2$: There is a significant positive causal relationship between systemic governance of smart complementarities and environmental sustainability.

$H_3$: There is a significant positive causal relationship between systemic governance of smart complementarities and social sustainability.

Table 3.1 provides a road map for the dissertation, including the research objectives, research questions and chapter addressed.

**Table 3.1:** A road map of research objectives, research questions and chapter addressed.

| Research Objectives | Research Questions | Chapter addressed |
|---|---|---|
| To map the interlinkages among smart city indicators | What are the synergies and trade-offs between the smart city indicators? | Chapter 2 |
| To develop a static and dynamic index for smart cities) | How did the ranking of smart cities evolve from 2005 to 2019? | Chapter 2 |
| To investigate the relationship between smart city enablers and urban sustainability | Does systemic governance of smart city drivers achieve urban sustainability? | Chapter 3 |

## 3.2. Research Design And Approach

This research follows a deductive approach in which a hypothesis is developed based on an existing theory, and then a research strategy is designed to test the hypothesis (Wilson, 2010). This explanatory study primarily examines the interlinkages between smart city indicators, i.e., smart city drivers and potential outcomes, including negative externalities, smart city impact on urban sustainability and the evolutions of smart cities over recent years. Towards this end, it applies a quantitative research method. A thorough review of the literature, empirical studies and econometric modelling were conducted to establish a robust econometric model to answer the research questions. Accordingly, three different methods are selected to achieve the thesis objectives. Each method is examined in detail in subsequent sections.

### 3.3. Data Collection

The study includes the smartest cities worldwide with a population of at least 100,000 inhabitants based on their ranking according to different indices: Smart City Index (2020), IESE Cities in Motion Index (2020), and Global Power City Index (2020). Accordingly, 33 smart cities with the longest time-series data from 2005 to 2019 were selected for this study (see Figure 3). The cities are from North America and Oceania, Europe, and Asia.[1]

For the purpose of quantitative analysis, secondary data was collected from official, well-known and reliable databases, including OECD, Eurostat, WDI, Global data lab, IDEA, Freedom House, etc. Missing values were treated using the imputation technique. In instances where city-level data were unavailable, the indicator was measured at the country level. The description of the indicators is presented in Table 3.2.




**Figure 3.1:** Map of the smart cities included in this study.

[1] The cities according to regions are **North American and Oceania:** Sydney (Australia), Melbourne (Australia), Brisbane (Australia) Vancouver (Canada), Montreal (Canada), Toronto (Canada), New York (United States), Washington (United States), Los Angeles (United States). **Europe:** Vienna (Austria), Brussels (Belgium), Copenhagen (Denmark), Prague (Czech), Tallinn (Estonia), Helsinki (Finland), Paris (France), Munich (Germany), Berlin (Germany), Frankfurt (Germany), Dublin (Ireland), Milan (Italy), Reykjavik (Iceland), Amsterdam (Netherlands), Oslo (Norway), Warsaw (Poland), Madrid (Spain), Barcelona (Spain), Bratislava (Slovakia), Stockholm (Sweden), Zürich (Switzerland), London (United Kingdom), Manchester (United Kingdom). **Asia:** Tokyo (Japan). Figure 3.1 presents the map of the smart cities included in the study.

**Table 3.2:** Smart city drivers, outcomes, and negative externalities.

| Driver | Indicator | Period | Data Sources |
|---|---|---|---|
| **Innovative Economy** | Innovation - Total R&D expenditure (%GDP) | 2000-2018 | OECD - Regions- |
| | Entrepreneurship - New business registered (per 1000 pop.) | 2006-2019 | WDI, US Census - Country level- |
| | Employment in knowledge-intensive sectors (% total emp.) | 2008-2019 | OECD - Regions-, BC Stats and Statistics Canada, Eurostat, NC Dashboard |
| | Innovation and sophistication factors (Business sophistication, capacity for innovation, university-industry collaboration in R&D, government procurement of advanced technology products, availability of scientists and engineers, patent applications, and intellectual property protection) | 2006-2017 | Weforum (GCI) -Country level- |
| **Community** | Education Index | 1990-2018 | GLOBAL DATA LAB |
| | Digital Proficiency: Ability of a society to make effective use of ICT | 2006-2017 | WDI(GCI) |
| | Creativity - Cultural employment (per 1000 pop.) | 2014-2019 | BEA's Arts and Cultural Production Satellite Account (ACPSA) statistics, BC |

| | | | |
|---|---|---|---|
| | | | Stats and Statistics Canada, Eurostat |
| **Physical & Natural Infrastructure** | Quality of Transport Infrastructure (1-7) (Quality of overall infrastructure, Quality of roads, Quality of railroad infrastructure, Quality of port infrastructure, Quality of air transport infrastructure, Available airline seat kilometres) | 2006-2017 | Weforum - Country level- |
| | Renewable energy consumption - (EJ Transformed per million) | 2000-2019 | Bp - Country level- |
| | Patents in environment-related technologies (Number) | 2000-2018 | OECD - Country level- |
| | Municipal Waste Treated (tonnes, thousands) | 2000-2019 | OECD- Country level- |
| **Technology** | Usage (1-7) (Individuals using the Internet, mobile subscription) | 2012-2016 | WDI - Country level- |
| | ICT infrastructure (1-7) (Electricity production-kWh/capita, Mobile network coverage-% population, International Internet bandwidth-kb/s per user, Secure Internet servers per million population) | 2012-2016 | WDI - Country level- Global IT report |
| **Governance** | Government effectiveness (-2.5-2.5) | 1996-2019 | WDI |
| | Digital Governance - E-Government development index (0-1) | 2003-2018 | United Nations (UNeGovKB) |

| | | | |
|---|---|---|---|
| | E-Participation Index (0-1) | 2003-2018 | United Nations (UNeGovKB) |
| | Civil society participation (0-1) | 2000-2018 | International Institute for Democracy and Electoral Assistance International IDEA) |
| **Outcomes** | Pollution index (Air quality, drinking water quality accessibility, water pollution, garbage disposal satisfaction, noise and light pollution, green and parks quality) (0-100) | 2012-2021 | NUMBEO |
| | Health - Life expectancy (Number) | 2000-2018 | GLOBAL DATA LAB |
| | Safety (Crime rate per 100000 pop) | 2000-2019 | OECD, Eurostat (Poland) |
| | Traffic Index (Time consumed in traffic due to job commute, estimation of time consumption dissatisfaction, $CO_2$ consumption estimation in traffic and overall inefficiencies in the traffic system) (0-100) | 2012-2021 | Numbeo |
| | Government transparency - Absence of corruption (0-1) | 2000-2018 | Idea |
| | Productivity - GDP per employed person (Constant 2015ppp$) | 2000-2018 | OECD, STATS NZ, Beijing Stats |
| | Flexibility in the labour market- Unemployment rate (%) | 2000-2018 | OECD, Eurostat, National |

| | | | |
|---|---|---|---|
| | | | Bureau of Statistics of China, BLS, Stats NZ |
| **Negative externalities** | Digital Divide* (0-3) | 2005-2019 | Freedom House |
| | Freedom of expression (0-1) | 2005-2019 | The Global State of Democracy (IDEA) |
| | Privacy issues* (0-6) | 2005-2019 | Freedom House |
| | Inequality (GINI) | Two years | U.S. Census (ACS)- OECD-Canada Census, Centreforcitites -Barcelona.cat |

The second part of the analysis uses balanced panel data for 26 smart cities from 2009 to 2019 selected for this study. The cities are from North America and Oceania, Europe, and Asia.[2] The description of additional smart city drivers and urban sustainability can be found in Tables 3.3 and 3.4, respectively.

To investigate the potential impact of smartness on urban sustainability, it is essential to use a multidimensional view of sustainability, i.e., economic, environmental, and social (Dur and Yigitcanlar, 2015; Yigitcanlar et al., 2018). Therefore, we test three models with each pillar of urban sustainability as the dependent variable. Economic and environmental sustainability are measured using gross national income and carbon dioxide emissions, respectively. Social

[2] The cities according to regions are **North American and Oceania:** Sydney (Australia), Toronto (Canada), New York (United States), Auckland (New Zealand). **Europe:** Vienna (Austria), Brussels (Belgium), Copenhagen (Denmark), Prague (Czech), Tallinn (Estonia), Helsinki (Finland), Paris (France), Berlin (Germany), Dublin (Ireland), Milan (Italy), Reykjavik (Iceland), Amsterdam (Netherlands), Oslo (Norway), Warsaw (Poland), Barcelona (Spain), Bratislava (Slovakia), Stockholm (Sweden), Zürich (Switzerland), London (United Kingdom). **Asia:** Tokyo (Japan), Beijing (China), Seoul (South Korea).

sustainability is proxied by health (life expectancy), safety (crime rate), social cohesion (GDI) and the right to employment (unemployment rate).

It is important to emphasise the rationale behind selecting carbon dioxide ($Co_2$) emissions as an indicator of environmental sustainability. First, the study focuses on the relationship between urban smartness and environmental sustainability over 10 years. $Co_2$ accumulates as a stock pollutant in the air, and its effects last for a century or more (Moore, 2009; Ukaogo et al., 2020), unlike flow pollutants, such as sulphur dioxide ($SO_2$), nitrogen oxide (NO), carbon monoxide (CO) and suspended particulate matter (SPM), which have only immediate environmental effects. Second, a high correlation between $SO_2$, NO and $CO_2$ proves that $CO_2$ emissions are a reliable measure that is also important for the short-run analysis (Hoffmann et al., 2005; Angelopoulos et al., 2010; Fischer and Heutel, 2013). Third, the availability of reliable time series data for $CO_2$ is another important reason for choosing this proxy.

The dependent variable is urban smartness. The arithmetic mean is used to aggregate individual indicators within each smart city driver. To align the indicators, a min-max transformation is applied to convert them into a scale from 1 to 7 as follows:

$$\textbf{Driver} = \frac{\sum_i^k Indicators}{k} \tag{3-1}$$

$$\mathbf{6 \times \frac{city\ score - sample\ minimum}{sample\ maximum - sample\ minimum} + 1} \tag{3-2}$$

The control variable in Model 1 is the percentage of GDP from services, which is the change in the structure of the economy and employment or quality of growth (Yi et al., 2019; Fan et al., 2019; Tan and Lu, 2016; Li and Yi, 2020). Model 2 incorporates population density, which affects the relationship between environmental sustainability and urban smartness (Alam and Kabir, 2013). Finally, Model 3 includes GDP growth, which translates into better health, education, economic well-being and quality of life (Younis and Chaudhary, 2017).

**Table 3.3:** Additional smart city drivers.

| Driver | Indicator | Period | References | Data Sources |
|---|---|---|---|---|
| **Technology** | Affordability (Prepaid mobile cellular tariffs, PPP $/min/Fixed broadband Internet tariffs, PPP $/month/ Internet and telephony sectors competition index) | 2012-2016 | Nicolas et al. (2020) | 4th Pillar-The Global IT Report-Country level- |
| **Governance** | Digital interest (e-gov, Government ICT usage, Laws relating to ICTs) (1-7) | 2003-2018 | Akman et al. (2005); Gil-Garcia et al. (2014). | WEF |
| | (e-participation/participatory engagement) (0-1) | 2003-2018 | Simonofski et al. (2017), Joshi et al. (2016) | United Nations (UNeGov KB), IDEA |
| | Env. Policy stringency index (0-6) | 2005-2015 | Caragliu et al. (2013), Inayatullah (2011) | OECD |

**Table 3.4:** Urban sustainability indicators and control variables.

| | Indicators | Period | References | Data Sources |
|---|---|---|---|---|
| Economic sustainability | GNI per capita | 1990-2018 | Lee and Huang (2007) Phillis et al. (2017) | GLOBAL DATA LAB |
| Environmental sustainability | Carbon emissions (Metric tons per capita) | 2012-2021 | Lee and Huang (2007) Lautso et al. (2002) | WDI |
| Social sustainability | Health (Life expectancy) | 1990-2018 | Dalevska et al. (2019) | GLOBAL DATA LAB |
| | Safety (Crime rate) | 2000-2019 | Meegan & Mitchell (2001) | OECD |
| | Social Cohesion (GDI) | 1990-2018 | Bramley et al., (2009) | GLOBAL DATA LAB |
| | Right to Employment (Unemployment rate) | 2000-2019 | Hopwood et al. (2005) | OECD |
| Control Variables | Growth quality (%GDP in services) | 1990-2018 | Yi et al. (2019) Fan et al. (2019) | OECD |
| | Population Density | 2000-2020 | Alam and Kabir (2013) | OECD |
| | GDP growth | 1990-2019 | Younis and Chaudhary (2017) | OECD |

### 3.4. Data Analysis

In this section, three empirical approaches are used to address the three research questions. Firstly, network analysis is employed to map the interlinkages among smart city drivers and outcomes. Secondly, dynamic factor analysis is utilised to track the development of smart cities, and thirdly, panel var analysis is applied to investigate the relationship between smart city drivers and urban sustainability. In turn, the three methodologies will be examined in the latter sections.

#### 3.4.1. Network Analysis (Mapping the Interlinkages between Smart City Drivers and Outcomes: The need for Integration and Harmonised Policies)

Network analysis is a powerful tool for conducting dynamic analyses to model the complex interactions between smart city indicators, which has not yet been achieved in the available literature. Therefore, the use of network analysis in this study is relevant because it helps break down the complexity of the smart city notion, deepens the current understanding of the relational structure between smart city dimensions, shows the interconnections and interdependencies in a systematic and integrated way, and provide sophisticated concepts, such as community detection and centrality measures. This, in turn, provides valuable theoretical and practical insights into the phenomena under study. Specifically, network analysis examines the activities of an individual indicator at the micro level, the structure of associations at the macro level, and the interaction between the two. Examining this macro–micro connection is key to network analysis algorithms, which distinguishes it from simple correlation analysis (Stokman, 2004).

Specifically, the contributions of network-based analysis of smart cities are manifold. First, it can help map and visualise the networks that underpin the various drivers and outcomes of smart cities. In specific, network analysis allows demonstrating and including the outcomes in the analysis of smart cities by mapping the relationships between different drivers within the smart city and understanding how these relationships contribute to the outcomes of the policy. Examining the structure of these networks and the connections between the different components enables policymakers to identify bottlenecks and inefficiencies in smart city policies in order to develop targeted interventions to improve the efficiency and effectiveness of these systems. Second, network analysis helps identify the most influential drivers of smart cities by using centrality measures that could refine the current understanding

of what makes a city smart and thus lead to effective policy formulation. Network analysis enables this by combining a large number of indicators into a single analysis without ignoring the potential interconnections between each smart city indicator. Third, network analysis can help coordinate the activities of the various stakeholders in a smart city by identifying the most effective coordination channels that will ensure that the resources and efforts of different actors are aligned towards the common goal of developing a successful smart city initiative. Fourth, community detection reveals the underlying community structure by dividing smart city drivers based on relationships or common properties. This can assist policymakers in making data-driven decisions and strategically selecting and prioritising the drivers that can work together to achieve the desired outcome.

This study presents an integrated analytical framework for network analysis of smart city drivers and outcomes interlinkages for 33 selected smart cities. This approach has been used previously in sustainable development research, e.g., by Swain and Ranganathan (2021), Pizzol et al. (2013), and Van Zaten and Van Tulder (2021).

A network is a graph containing a set of nodes (mathematically called vertices) connected by edges (links). A node can represent any construct from any domain of interest, e.g., a person or a country, which together form a network. An edge furnishes information about the nature of the relationship between two nodes, with weighted edges indicating the strength of the relationship and unweighted edges providing information about whether a link exists (Barabási, 2003). In essence, two indicators can be positively or negatively related, with the former referred to as synergy and the latter as a trade-off. For instance, a synergy exists between GDP growth and literacy rate if an increase in literacy leads to an increase in GDP growth, i.e., there is a positive correlation coefficient. A crucial aspect for the correct interpretation of the linkage is whether these indicators are specified in the same or the opposite direction, i.e., a favourable result requires an increase in one indicator and a decrease in the other, as in the relationship between GDP growth and poverty rate.

After identifying the structure of the relationships in terms of synergies and trade-offs, the strength of the linkages is quantified and weighted by the correlation coefficient (−1 to 1) between the panel data of the two indicators as follows:

$$\rho_{xy} = (1/(\mathrm{Sdx} * \mathrm{Sdy}))(1/N)(1/(\mathrm{T}-1)) \sum_{i=1}^{N} \sum_{t=1}^{T} (Xi(t) - \overline{Xi})\,(Yi(t) - \overline{Yi}) \qquad (3\text{-}3)$$

where N represents cities, T years, $\overline{Xi}$ and $\overline{Yi}$ time-average of X and Y, respectively.

A threshold was also defined to evaluate the importance of the links. After creating a directed and weighted network of linkages among the smart city dimension indicators, the network was analysed using network statistics called centrality measures to capture the most influential nodes in the network. These measures include degree centrality, betweenness centrality, eigenvector centrality, and closeness centrality. Each measure provides a different definition and result. An indicator with high centrality plays a pivotal role with major connections to other indicators in the network. In practice, these measures serve as an effective tool for policymakers to decide which variables to prioritise and establish an appropriate policy framework.

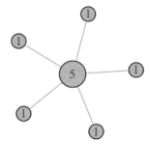
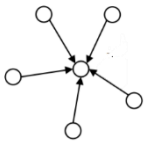
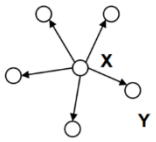
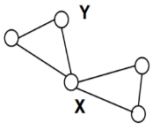
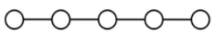
Centrality measures could be neighbour-based measures that focus on the node and its immediate neighbours (Swain and Ranganathan, 2021). These include degree centrality, which measures the number of other nodes connected to a given node (Freeman, 1978). Thus, an indicator that has a high degree of centrality is closely related to other indicators, and targeting such indicators has direct implications. In directed networks, there are in- and out-degree measures, with the former indicating the number of connections from all network nodes to the node in question and the latter showing the number of connections from the node in question to the other nodes. That is, achieving an indicator with high in-degree centrality requires the implementation of indicators that directly influence it. In contrast, the implementation of an indicator with high out-degree centrality has an immediate impact on other indicators.

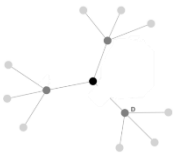
Other centrality measures are path-based measures that consider the position of nodes, taking into account the different paths in the network (Swain and Ranganathan, 2021). These include eigenvector centrality, which extends the concept of degree centrality by considering both the number and importance of node neighbours. This means that an indicator with high eigenvector centrality is intertwined with many other influential indicators, and thus, addressing such indicators can potentially strengthen other indicators. Closeness centrality, another path-based centrality measure, estimates the average distance of a given node from all other nodes (Borgatti, 2005). A node with high closeness centrality has short distances to

all other nodes within the network and therefore has a direct impact on the other nodes. (Betweenness centrality is also a path-based measure, which quantifies the degree to which nodes stand between each other, which signifies the influence a node has on the flow of information in a network (Freeman, 1978). A high betweenness centrality indicates how important an indicator is in bridging other indicators that are not interconnected (Swain and Ranganathan, 2021). Therefore, efficient and economic benefits can be obtained by focusing on the indicators that link to various other indicators. Table 3.5 includes illustrations and the formulas of the various centrality measures.

In addition to centrality analysis, a community detection algorithm was used in this study to identify overlapping communities according to their connectivity patterns – a high probability of being connected to each other rather than to other nodes. In other words, similar smart city indicators were identified and grouped into different dimensions that might differ from the original set of dimensions. This way, important indicators can be identified and efficiently managed by policymakers. Community detection is based on the algorithm of Blondel et al. (2008).

**Table 3.5:** Centrality measures.

| Centrality | Definition | Formula | Representation |
|---|---|---|---|
| **Degree** | The number of edges connected to the node | $C_D(v_i) = d_i = \sum_j A_{ij}$ |  |
| **Indegree** | The number of ingoing edges connected to a node | $k_i^{\text{in}} = \sum_{j=1}^{n} A_{ij}$ |  |
| **Outdegree** | The number of outgoing edges connected to a node | $k_j^{\text{out}} = \sum_{i=1}^{n} A_{ij}$ |  |
| **Betweenness** | The extent to which a node lies on paths between other unconnected nodes. | $C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$<br>Where gjk(i)= the number of shortest paths between jk passing through node i<br>gjk = total number of shortest paths |  |
| **Closeness** | The mean distance from a node to other nodes. It is the inverse of the sum of the shortest distances between the | $C_c(i) = \left[\sum_{j=1}^{N} d(i,j)\right]^{-1}$ |  |

| | | | |
|---|---|---|---|
| | node and other nodes in the network. | | |
| **Eigenvector** | It extends the degree centrality by taking into account the importance of the node's neighbours. | $x_v = \frac{1}{\lambda}\sum_{t\in M(v)} x_t = \frac{1}{\lambda}\sum_{t\in G} a_{v,t}x_t$<br>M(v) = Neighbourhood of Xv<br>G= Adjacency Matrix of the graph |  |

Newmann, Networks: An Introduction, Oxford University Press (2010).

In this study, each driver/outcome indicator is represented by a node in the network, and the importance of the interlinkages between the indicators helped determine the existence of the edge between the nodes. A directed, weighted, and signed network was used to visualise the network and to calculate the centrality measures. Finally, a modularity-based community detection algorithm was used to identify a similar group of indicators in the network over the period 2005-2019. Figure 3.2 shows the roadmap for network analysis in this study.

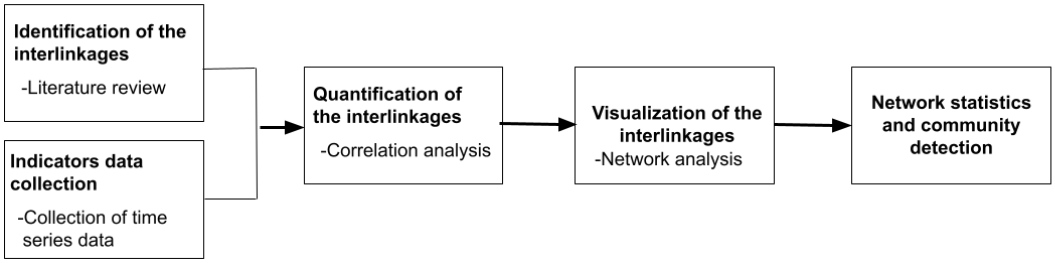



**Figure 3.2:** Roadmap for network analysis.

### 3.4.2. Dynamic Factor Analysis (Developing a Static and Dynamic Index for Smart Cities)

Dynamic factor analysis was developed by Coppi and Zannella (1978) and re-examined by Coppi (1986) and Corazziari (1997) as a multivariate statistical technique to study complex phenomena/data structures. This method has been applied in various research areas (Song and Xie, 2021; Castellano and Rocca, 2017). Dynamic factor analysis combines the cross-sectional analysis of the factor model with the time series analysis of the linear regression model to analyse the dynamic changes in the panel data and incorporate the common trends to identify the commonalities of the three-dimensional data (observations, variables, and time). While the traditional factor analysis model emphasises the static changes in cross-sectional or time series data and does not reflect the dynamic changes in the data, dynamic factor analysis captures both the dynamic and static perspectives of the data.

Dynamic factor analysis is a functional method for the data matrix X organised in three arrays, namely units, variables, and times, to analyse the "volume" of the data:

$$\mathbf{X(I, J,T) = \{Xi,j,t\}, i= 1…., I, j=1….., J, t=1…,T.} \quad (3\text{-}4)$$

Where i is the unit, j is the variable and t the time.

X is reduced to a matrix of the dimensions IT X J by stringing together the matrices $\{X_t, t= 1,...,T\}$, where $X_t$ is the matrix units of the variables observed at time t. In other words, dynamic factor analysis decomposes the variance and covariance matrix S in terms of X(IT, J), where the units are given by the pairs 'units-times'.

The variance-covariance matrix S of X (I , J , T) is divided into the sum of three different variance and covariance matrices or the mean dispersion matrix and the mean dynamic matrix, that is:

$$\mathbf{S = {}^{*}S_I + {}^{*}S_T + S_{IT} = ({}^{*}S_I + S_{IT})\ {}^{*}S_T = S_T + {}^{*}S_T} \quad (3\text{-}5)$$

Where $^{*}S_I$ is the matrix of the static structure of the units, that is, the average of the units with respect to time, which reflects the variability of the relational structure of the units independent of the time dimension. Its general element is:

$$_{jj'} = \sum_i (\overline{x_{ij.}} - \overline{x_{.j.}})(\overline{x_{ij'.}} - \overline{x_{.j'.}})\, d_i \quad (3\text{-}6)$$

Where di is a weight attributed to units.

*$S_T$ is the matrix of the average dynamics of the system reflecting the variability due to the time dimension for the average of each variable over the units, independent of the dynamics of the individual units (between variability), obtained from the linear regression model. Its general element is:

$$ {}_tS^*_{jj'} = \sum_t ( \overline{x_{.jt}} - \overline{x_{.j.}} ) ( \overline{x_{.j't}} - \overline{x_{.j'.}} ) l_i \quad (3\text{-}7) $$

Where $l_t$ is a weight attributed to time;

$\overline{x_{.jt}}$ is the dependent variable of the following regression model: $\overline{x_{.jt}} = a_j + b_jt + e_jt$; j = 1; . . .; J; t = 1; . . .; T, provided that the residuals satisfy the condition below:

$$ \mathbf{cov}(e_{jt}, e_{j't'}) = \begin{cases} w_j & j=j';t=t' \\ 0 & otherwise \end{cases} \quad (3\text{-}8) $$

This condition implies that the average dynamics of the system are different from the average dynamics of the individual variables since the relationship between the j variables is only explained by the principal component analysis relative to the ST matrix.

$S_{IT}$ is the matrix of the differential dynamics of the individual units, reflecting the interaction between units and times of the values (heterogeneous part of each sample) and $S_T$ refers to the mean dispersion matrix within time resulting from principal component analysis (within variability).

Building on the decomposition of the total variability in Equation 3-4, the generic element $x_{ijt}$ can be expressed as the sum of four different components:

$$ x_{ijt} = \overline{x_{.j.}} + ( \overline{x_{ij.}} - \overline{x_{.j.}} ) + \left( \overline{x_{.jt}} - \overline{x_{.j.}} \right) + (x_{ijt} - \overline{x_{ij.}} - \overline{x_{.jt}} + \overline{x_{.j.}}) \quad (3\text{-}9) $$

Where: $\overline{x_{.j.}}$ is the overall average of the single variable;

$( \overline{x_{ij.}} - \overline{x_{.j.}})$ is the effect due to the static structure of the units;

$\left( \overline{x_{.jt}} - \overline{x_{.j.}} \right)$ is the effect due to average dynamic; and

$(x_{ijt} - \overline{x_{ij.}} - \overline{x_{.jt}} + \overline{x_{.j.}})$ is the effect produced by the different dynamics or interactions between units and times.

Equation 3-8 represents a two-factor model for the analysis of variance that accounts for the various components of Equation 6 and the elements of the total variability in Equation 3-3 in terms of the principal component analysis and a linear regression model. It can be noticed that dynamic factor analysis decomposes the total variability of X(IT, J) into three components, namely units, variables, and times, thus accentuating the different aspects of the three-dimensionality of the phenomenon.

In essence, dynamic factor analysis encompasses several stages. First, the standardisation of data to remove the influence of dimensions and unify the type of indicators as follows:

$X_{ijt} = (x_{ij} – avg(x.j.))/sd(x.j.)$
(3-10)

Where *avg*(*x.j*.) refers to the mean value of the $j_{th}$ index and *sd*(*x· j·*) refers to the standard error of the $j_{th}$ index.

Second, to account for the influences of the static structural differences and the dynamic variation of the data, the variance-covariance matrix S(t) of the different years is employed to solve the mean variance-covariance matrix ST.

$$\mathbf{S_T} = \frac{1}{T}\sum_{t=1}^{T} \boldsymbol{S}(\boldsymbol{t}) \quad (3\text{-}11)$$

Third, the variance and cumulative variance contribution rates of the common factors are calculated using the eigenvalues of the mean variance-covariance matrix ST and their corresponding eigenvectors. Fourth, the number of common factors of the urban smartness assessment indices is determined based on the calculated cumulative contribution rates and principal components. Fifth, the static and dynamic score matrices of each sample are calculated based on the extracted principal components and their corresponding variance contribution rates as shown in Equations 3-11 and 3-12, respectively.

$$\mathbf{C_{ih}} = (\overline{\boldsymbol{Z_i}} - \overline{\boldsymbol{Z}_{\cdot}})'. \mathbf{a_h} \quad (3\text{-}12)$$

Where: $\overline{Z_i} = \frac{1}{T}\sum_{t=1}^{T} Z_{it}$

$\overline{Z_{\cdot}} = \frac{1}{I}\sum_{t=1}^{I} \overline{Z_i}$

$Z_{it}$' = ($Z_{i1t}$, $Z_{i2t}$,…..,$Z_{iJt}$), i= 1, 2, . . . , *I*; *h* = 1, 2, . . . , *H*; and *t* = 1, 2, . . . , *T*.

$a_h$ is the eigenvector corresponding to the mean variance–covariance matrix $S_T$.

$$\mathbf{C_{iht} = (\overline{Z_{it}} - \overline{Z_{.t}})'. a_h} \quad (3\text{-}13)$$

Where: $\overline{Z_{.t}} = \frac{1}{I}\sum_{t=1}^{I} Z_{it}$ , i= 1, 2, . . . , *I* , *h* = 1, 2, . . . , *H*, and *t* = 1, 2, . . . , *T*.

Finally, the sample's mean smart score matrix, SMART, is calculated using the static and dynamic scores. Figure 2 shows the schematic layout of the study methodology.

$$\mathbf{SMART} = \frac{1}{T}\sum \boldsymbol{c_{iht}} \quad (3\text{-}14)$$

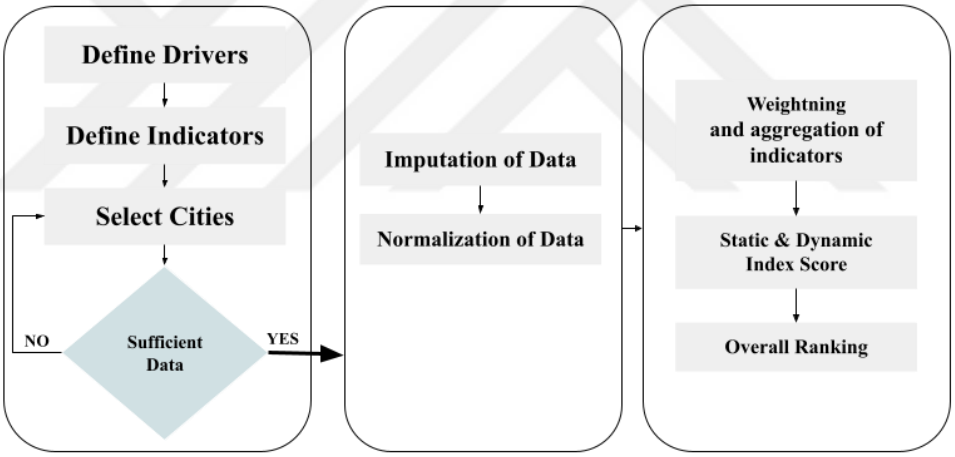



**Figure 3.3:** The schematic layout of the study methodology.

### 3.4.3. Panel VAR Analysis (Investigating the Relationship between Smart City Drivers and Urban Sustainability)

As mentioned in the previous sections, the motivation for this research is based on the notion that smart cities are gaining momentum as the primary solution to urban sustainability. Exploring this premise requires an interdisciplinary approach to translate smart solutions into sustainable outcomes, i.e., in terms of environmental, economic and social dimensions. Smart city models are indeed challenging in both theory and practice, and the available research on the potential impact of smart cities on sustainability is vague, limited, and inconclusive (Neuman, 2005; Bibri and Krogstie, 2017; Kärrholm, 2011). Therefore, we propose an integrated framework to assess and measure the impact of smart governance of smart cities on urban sustainability.

The complementarity analysis suggests that the co-occurrence of the smart city effect on urban sustainability is not coincidental. Rather, the formation of systemic governance is a deliberate attempt to improve sustainability, and these arrangements have created a system of complementary institutions that effectively improve the smart city outcome. In other words, the institutional complementarity hypothesis is best suited to explain many factors in any policy. It can determine whether institutions function effectively and how they are implemented in the current institutional structure (Boyer, 2005).

To gain valuable insights, longitudinal studies are extremely useful for testing causal relationships and dynamics where other research designs may not help explain or identify specific relationships (Ruhlandt, 2018). Towards this end, panel var analysis is used to explore the relationship between variables of interest. This method has been used extensively in the sustainable development literature (Vo, 2021; Simionescu, 2021; Swain and Karimu, 2020; Kayani et al., 2020; Robaina and Madaleno, 2020; Latief et al., 2020; Wang et al., 2020 and Antonakakis et al., 2017).

The advantages of Panel VAR are manifold. First, it allows for capturing dynamic interactions among variables over time. By examining the co-movements of different variables, PVAR analysis can help identify the causal relationships between them. Second, it accounts for unobserved individual heterogeneity by combining the traditional VAR approach of treating variables as endogenous with the panel data approach (Love and Zicchino, 2006). Third, it also allows for the identification of both short-term and cumulative long-term effects between variables (Ahortor et al., 2009).

Finally, PVAR captures how certain variables respond to unexpected changes in other variables over time.

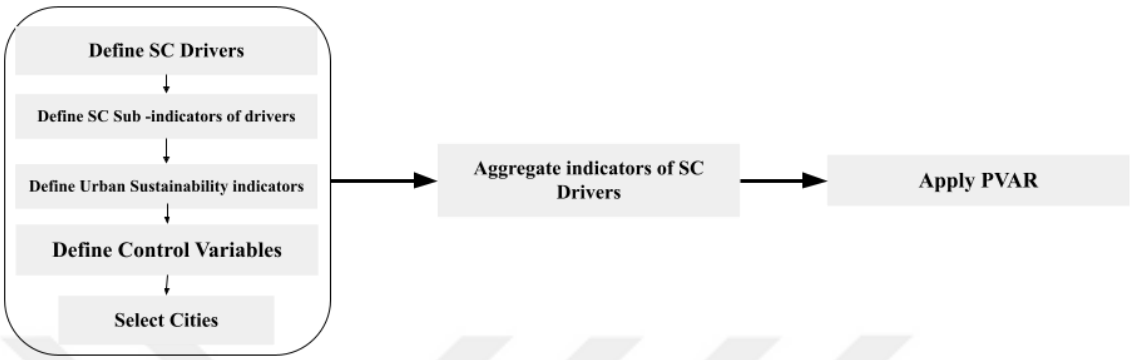



**Figure 3.4:** The PVAR research methodology.

The first step is considering whether to apply the first- or second-generation unit root tests based on cross-sectional dependence results (CD). Failure to consider cross-sectional dependence could have serious consequences, such as weakening the conclusions and results of the unit root tests. The test of Pesaran's (2004) CD is specified as follows:

$$CD_P = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \rho_{ij}\right) \quad (3\text{-}15)$$

T is the time, N is the cross-section dimension, and $\rho_{ij}$ is pair-wise correlation coefficients (Pesaran, 2004).

The second step is to check the stationarity of the variables. The unit root test of Pesaran's CIPS (2007) for heterogeneous panels extends the typical Augmented Dickey-Fuller test (ADF) to include the average values of the cross-section of the lagged level and the first difference of each time series. The CIPS test is as follows:

$$CIPS\ (N,T) = N^{-1} \sum_{i=1}^{N} t_i(N,T) = \frac{\sum_{i=1}^{N} CADFi}{N} \quad (3\text{-}16)$$

Where N is the number of cross sections; T is time; CADF is ADF statistic of the cross sections (Pesaran, 2007).

The third step is to examine the existence of the long-run cointegration relationship in the panel data using Westerlund's (2008) Durbin-Hausman panel

cointegration test. The test comprises two subtests - DHg test for the group mean statistic and DHp test for the panel statistic.

$$DH_g = \sum_{i=1}^{n} S_i(\emptyset_i - \emptyset_i)^2 \sum_{t=2}^{T} e_{it-1}^2 \quad (3\text{-}17)$$

$$DH_p = S_n(\emptyset - \emptyset)^2 \sum_{i=1}^{n} \sum_{t=2}^{T} e_{it-1}^2 \quad (3\text{-}18)$$

Where $\emptyset_i$ is the OLS estimator of $\emptyset_i$, $S_i$ and S are variance ratios.

The panel VAR model can be defined as:

$$Y_{i,t} = B_0 + \sum_{j=1}^{P} \boldsymbol{Bj}\ Y_{i,\,t-j} + \mu_i + e_{i,t} \quad (3\text{-}19)$$

Where $Y_i$ represents the dependent variables in each model which are: economic sustainability, environmental sustainability, and social sustainability.
$B_0$ is the intercept term vector, $B_j$ represents the coefficient of the lagged term to be estimated, $\mu_i$ is a measure of heterogeneity between observation units, $e_{i,t}$ is the random error.

The panel VAR model is estimated using the generalised method of moments (GMM) as it is considered an efficient and robust estimator (Abrigo and Love, 2016; Murphy and O'Reilly, 2019). The study estimates the following models:

Model 1: $GDP_{i,t} = f$ (TECH, COM, GOV, IECO, GDPSER) (3-20)
Model 2: $E_{i,t} = f$ (TECH, COM, GOV, IECO, DEN) (3-21)
Model 3: $S_{i,t} = f$ (TECH, COM, GOV, IECO, GDPG) (3-22)

After checking the stability conditions of the estimated models, the impulsive response function demonstrates the responses of one variable in the model to the random shock of another variable, while the influence of the other variables is set to zero. The decomposition of error variance is further explored to illustrate the variability explained by the variations in the explanatory variables. These instruments are expressed as follows:

$$\text{IRF: } Y_{it+h} - E\,[Y_{it+h}] = \sum_{i=0}^{h-1} \boldsymbol{ei}(t+h-i)^{\emptyset_i} \quad (3\text{-}23)$$

$$\text{EVD: } \emptyset_i = \begin{cases} \boldsymbol{I_K} & \boldsymbol{i = 0} \\ \sum_{j=1}^{i} \emptyset_{t-j} \boldsymbol{Aj} & \boldsymbol{i = 1, 2, \ldots.} \end{cases} \quad \text{(3-24)}$$

After estimating the PVAR model, we construct the panel Granger causality test of Dumitrescu and Hurlin (2012). The panel Granger causality test can be obtained as follows:

$$w_{i,t} = n_i + \sum_{i=1}^{b} \boldsymbol{c_i^{(b)} w_{i,t-b}} + \sum_{i=1}^{b} \boldsymbol{l_i^{(b)} v_{i,t-b}} + u_{i,t} \quad \text{(3-25)}$$

Where $n_i$ is the constant term, $c_i^{(b)}$ the lag parameter, $l_i^{(b)}$ the coefficient slope, and *w* and *v* signify each time two of the examined variables to check the causality as a pair.

To investigate whether the systemic governance of smart complementarities leads to urban sustainability, we need to confirm the existence of smart complementarity. Thus, the variables should meet the following criteria: the existence of a unidirectional or bidirectional positive causal relationship between variables that supplement one another to achieve positive synergy. A systemic mode of governance is confirmed when there are positive (smart) complementarities between all variables.

# CHAPTER FOUR
# FINDINGS AND DISCUSSIONS

## 4.1. Results And Discussions Of Network Analysis (What Are The Synergies And Trade-Offs Between The Smart City Drivers And Outcomes?)

This study aims to integrate and balance the key drivers of smart cities and potential outcomes by examining and quantifying the relationship between smart city indicators established in Chapter 2. After highlighting the interlinkages between the indicators (see Figure 4.1), three thresholds are established according to Ratner (2009) to determine the strength of the relationship (high = 0.7, medium = 0.5, low = 0.2). This quantification is derived from the pairwise correlation of the indicators. Figures 4.2, 4.3 and 4.4 depict the map of interdependencies and the network visualisation at low, medium, and high thresholds, respectively. It is worth noting that the network visualisation in terms of synergies and trade-offs is based on theoretical identification rather than the sign of the correlation coefficient. This is because the presence of a correlation does not imply a causal relationship, and the sign could erroneously point in a different direction. Accordingly, positive correlations mean that targeting a particular indicator has a positive influence or feedback on the other indicators and vice versa.

On the other hand, the map of linkages contains the results of both the theoretical and empirical analyses, highlighting the differences between the results in the map. The conflicting results between the theoretical and empirical analyses may be due to the choice of the proxy to measure the indicator or, as mentioned earlier, due to the direction of causality.

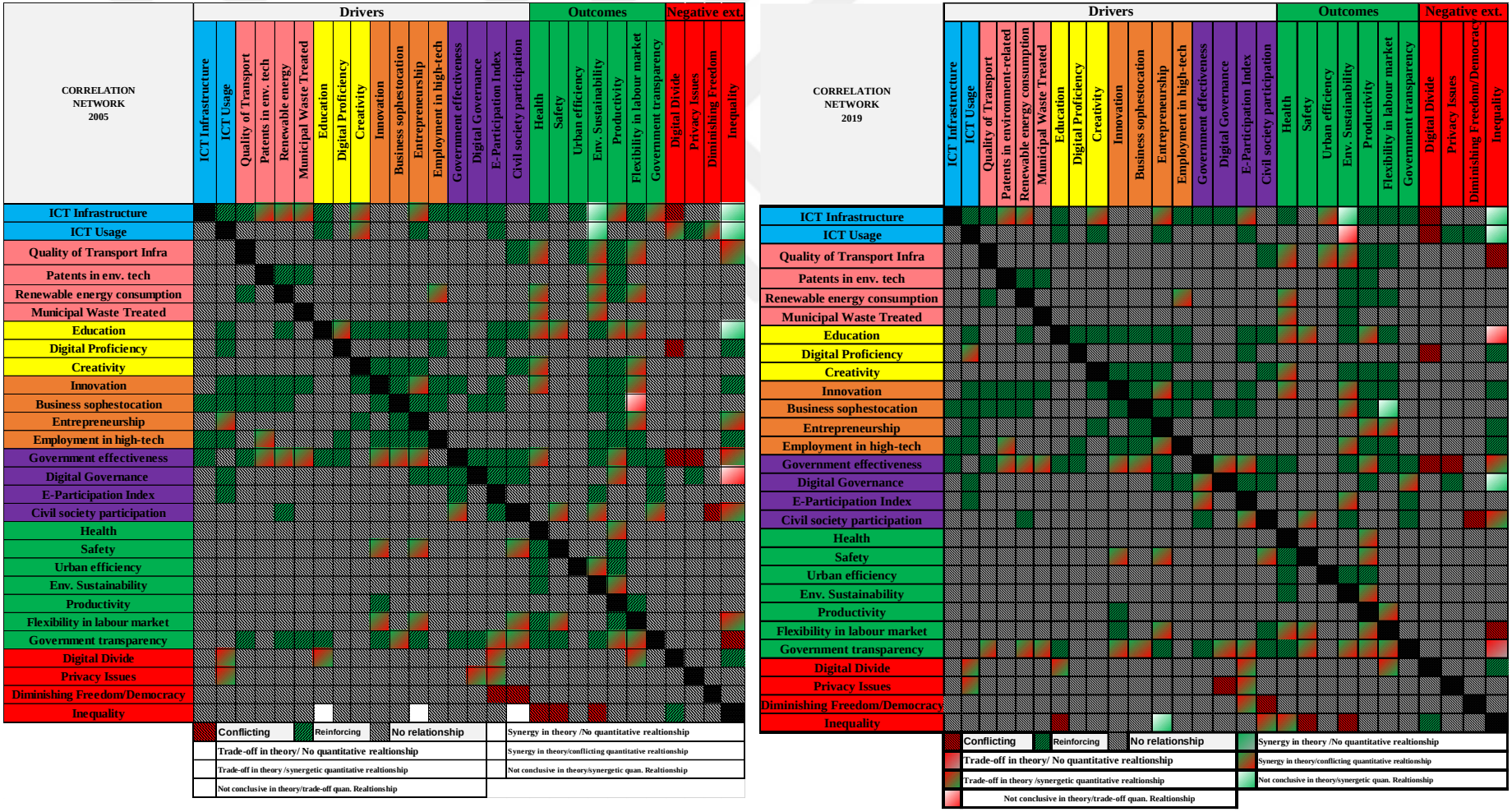



**Figure 4.1:** Map of the interlinkages in 2005 and 2019.

Comparing relationships in 2005 and 2019 can reveal how the impact of smart city projects has changed over the years due to their maturity and the widespread adoption of these initiatives in each country. For instance, several relationships are found to have improved in 2019 compared to 2005: (i) ICT infrastructure, quality of infrastructure, productivity, government transparency, and creativity; (ii) ICT use, education, creativity, and entrepreneurship; (iii) patents in environment-related technologies, waste treatment, renewable energy consumption, and environmental sustainability; (iv) government effectiveness, ICT infrastructure, digital proficiency, business sophistication, entrepreneurship, environmental sustainability, and government transparency; (v) digital governance, ICT use, entrepreneurship, and productivity.

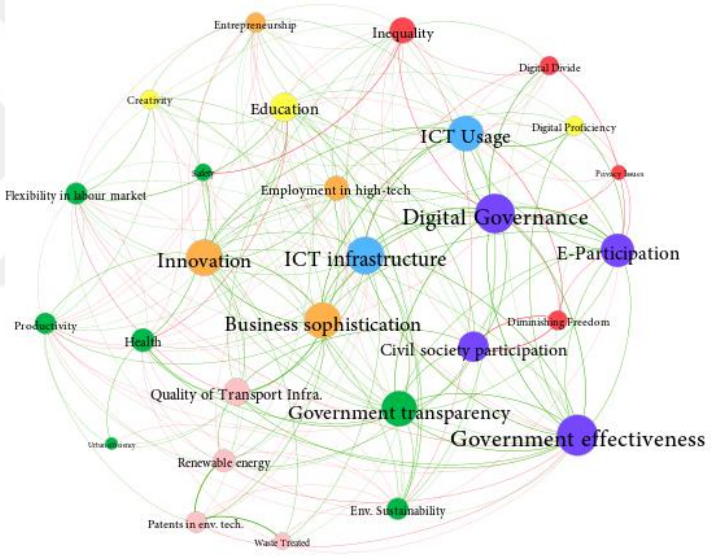



**Figure 4.2:** Correlation network for smart city indicators over the period 2005-2019 with a low threshold.[3]

[3] Each node indicates a smart city indicator, and each directed link between two indicators represents the causal relationship between them. The network is generated using the 'Force Atlas 2'. Red, yellow, green, blue, brown, and purple nodes represent the indicators that belong to the smart economy, smart people, smart environment, smart living, smart mobility, and smart governance, respectively. The size of the nodes is scaled in accordance with the level of weighted degree. The thickness of the edge is based on their weights. Green and red edges represent synergy and trade-off, respectively. The direction of the edge (clockwise or counter-clockwise) represents the direction of the relationship.

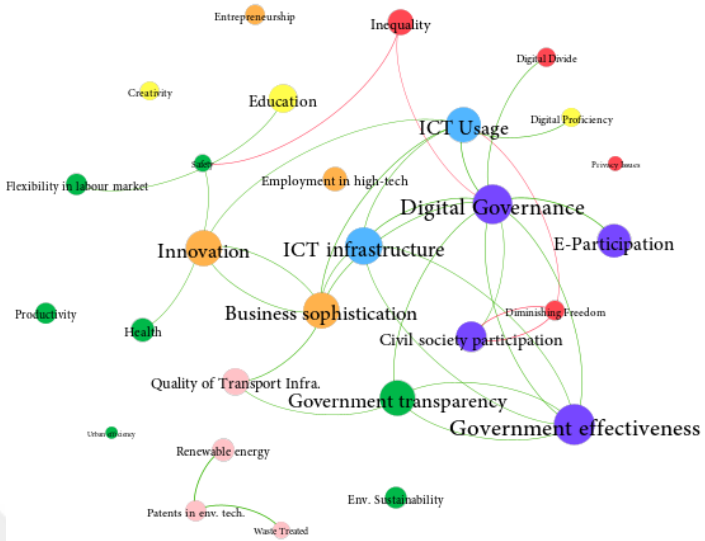



**Figure 4.3:** Correlation network for smart city indicators over the period 2005-2019 with a medium threshold.

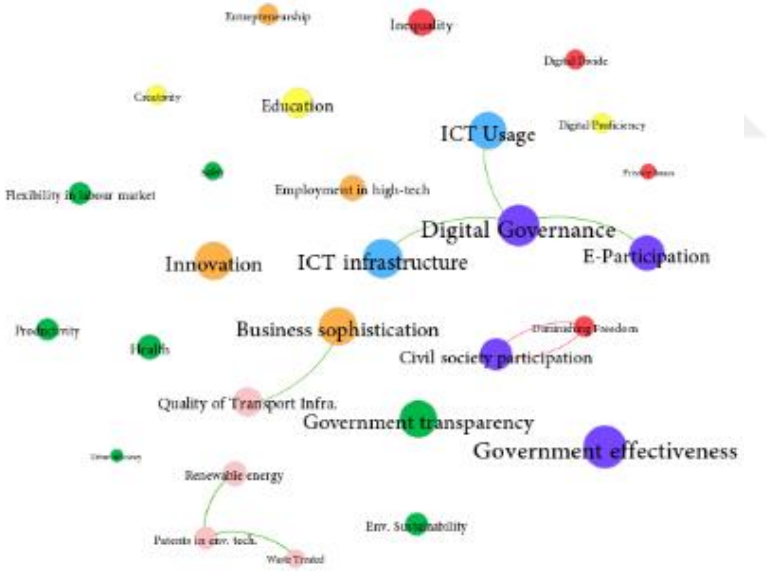



**Figure 4.4:** Correlation network for smart city indicators over the period 2005-2019 with a high threshold.

The results of the theoretical interlinkages and correlation values over the period 2005 to 2019 suggest the existence of both synergies and trade-offs in the network, which may be the chief reason for ineffective policies. We found evidence of 152 synergies out of 220 indicators (69%), while 68 trade-offs (31%) exist. However, most of the trade-offs in the network have a low threshold value, which means the trade-offs are weaker than the synergistic relationships.

For example, Figure 4.4 shows no trade-offs at the high threshold. This indicates that policymakers can focus on strong positive synergies as the net impact of the trade-offs appears to be weak. The strongest synergies remain with (i) ICT infrastructure, ICT use, e-governance, and e-participation; (ii) Waste treatment, renewable energy, and patents in environment-related technologies; (iii); Business sophistication and quality of infrastructure; and (iv) participation and increased freedom. Further analysis at the city level is needed to confirm these results, as the data may significantly affect these results.

To visualise the network, three directed and weighted networks were created on the basis of the identified synergies and trade-offs and the correlation value (visualisation of 2005 and 2019 networks are presented in Appendix A). The correlation value ranges from −1 to 1, where the sign of the correlation depends on the identified relationship. Evidently, the network's density (the number of edges) decreases at high thresholds, which means that a few strong relationships survive. For instance, at a threshold of 0.2, there are 221 edges, while at medium and high thresholds, there are 31 and 8 edges, respectively. Another possible function of network visualisation is to provide a detailed and direct mapping of the potential synergies and trade-offs for a particular driver, such as innovation, as shown in Figure 4.5. For example, the sub-network containing the interlinkages between the key driver innovation and other indicators in the network shows all potential synergies and trade-offs. A closer look reveals positive relationships can be located, such as productivity, government effectiveness, environmental sustainability, and ICT infrastructure, implying that policies that promote innovation also strengthen these indicators. Similarly, negative connections, such as entrepreneurship are found. This result suggests that the higher number of business start-ups is not due to innovation but higher unemployment rates, especially since we found a positive relationship between the latter two factors.

This analysis provides an opportunity to explore one of the hottest topics in the literature, the impact of ICT infrastructure and technology use on the digital divide, privacy, freedom of speech, and inequality. Preliminary results show a positive relationship between ICT diffusion and penetration and digital inclusion. There is also a positive relationship between digital literacy, ICT use, and digital inclusion. Nevertheless, ICT use and digital literacy correlate positively with increasing inequality, while ICT use is negatively related to privacy issues and decreasing

freedoms, respectively. Similarly, there is a negative correlation between e-government, e-participation, and privacy issues, as well as diminishing freedoms.

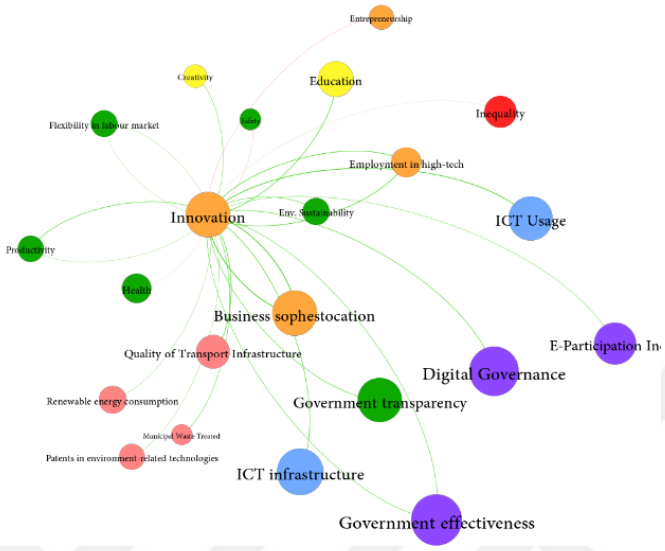



**Figure 4.5:** Visualization of a sub-network that focuses on the interlinkages between innovation and other indicators in the network.[4]

The network centrality measures for the smart city indicators are provided in Appendix A, Table A.1, Table A.2 and Table A.3. As noted earlier, a directed and weighted network was used to compare the smart city drivers according to different centrality measures, which yield slightly different results depending on the measure used. The results show that innovation, business sophistication, government effectiveness, ICT infrastructure, ICT usage, education, and digital governance are the most important indicators in the network as measured by the different centrality measures. Specifically, according to weighted degree centrality, innovation, government effectiveness, ICT infrastructure, business sophistication, and digital governance are the five most important indicators in terms of their extensive connections as both influencers and recipients, which make them central to other indicators in the network.

In detail, stimulating the smart city drivers, such as innovation, government effectiveness, ICT infrastructure, digital governance, education, and business

[4] This application is based on the innovation indicator. Green edges represent synergies, and red ones indicate conflation. The thickness of the edge is based on their weights.

sophistication can both influence the successful achievement of other indicators and have a more efficient and direct impact on those indicators in the network, as measured by out-degree centrality and closeness centrality, respectively. On the other hand, e-participation, ICT usage, quality of infrastructure, and outcomes, such as health, productivity, and environmental sustainability are most influenced by the achievement of other indicators in the network, as measured by in-degree centrality. Another result shows that innovation, ICT usage, civil society participation, employment in high-tech, and government effectiveness play a mediating role in the network by connecting indicators that are not directly related, as shown by betweenness centrality. To confirm the reliability/robustness of the result, we carried out the same analysis for both 2005 and 2019 and reached the same conclusions.

After identifying the most influential drivers and potential outcomes using the centrality measures for effective policy formulation, community detection was applied to drivers solely to pin down the drivers that interact synergistically. This identification can assist policymakers in strategically selecting and prioritising drivers that can work together to achieve the intended outcome. This study identified three communities that include indicators that work simultaneously and reinforce each other to achieve the desired outcome, as shown in Figure 4.6. The first community (Digitalization) is the technological readiness of the smart city in addition to the effective governance that manages the digital transformation where it incorporates factors, such as ICT infrastructure, ICT usage, e-participation, digital proficiency, employment in high-tech, government effectiveness, digital governance, digital inclusion, and privacy rights policies. The inclusion of digital inclusion and privacy rights in the framework is essential, as these indicators significantly influence the use, diffusion, and success of digital governance and e-participation, which is also evident in the quantitative analysis.

The second community focuses on the human and social capital of the smart city goals and includes education, creativity, entrepreneurship, and civil society participation. The third community (Innovation and sustainable infrastructure) includes innovation, business sophistication, quality of transport infrastructure, patents in environment-related technologies, renewable energy, and waste treatment.

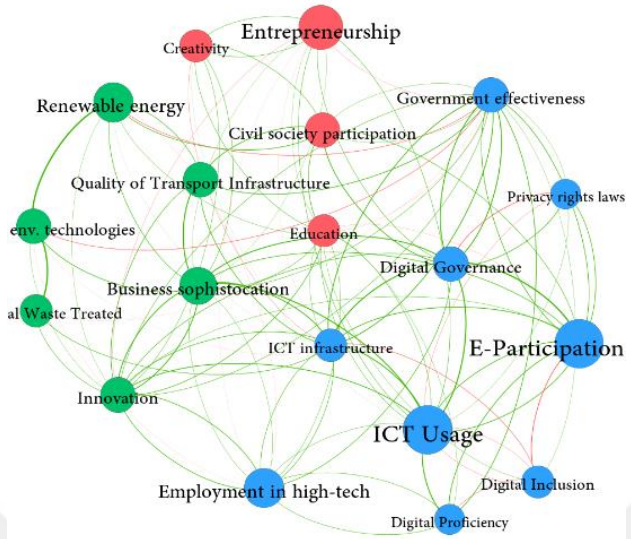



**Figure 4.6:** Smart city indicators network based on community detection (2005-2019).

In accordance with the community identification results, an updated smart city framework is proposed to enable policymakers to focus their efforts and make smarter decisions in choosing smart city policies, as shown in Figure 4.7. Unlike previous studies that used qualitative analysis for their proposed smart city frameworks, the proposed framework is based on a quantitative technique. This approach focuses on developing a smart agenda that not only depends on the technology itself but also leverages businesses and collaboration between city stakeholders, along with the active role of citizens, all under the umbrella of smart governance. These findings support the framework of Nam and Pardo (2011), who identified technology, people, and institutions as the key characteristics of a smart city, although our framework provides extended results. In particular, this framework has augmented the available frameworks by including policies that address current and debated issues, such as the digital divide and privacy and security concerns. The identified smart communities are critical to the development of a smart city, as smart infrastructure alone is not sufficient to implement a smart city, which is consistent with the recommendations of Shapiro (2006), Holland (2008), Albino et al. (2015), Angelidou (2015), Bibri and Krogstie (2017). The findings also include smart governance and business-led urban development, which is congruent with most previous studies on the drivers of smart cities.

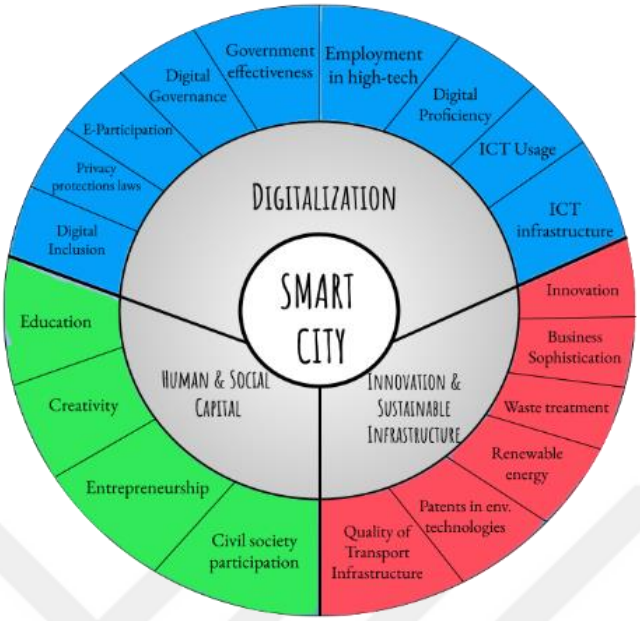



**Figure 4.7:** Proposed framework based on the results of community detection.

## 4.2. Results And Discussions Of Dynamic Factor Analysis (How Did Smart Cities Ranking Evolve From 2005 To 2019?)

To delineate the dynamic changes over time, a dynamic factor analysis is applied to the variables for the years 2005 to 2019 using the Stata procedure developed by Federici and Mazzitelli (2005). The dynamic factor analysis not only compares the urban smartness of different cities horizontally but also reflects the dynamic changes in urban smartness vertically.

To determine the common factors of the sample, the variance-covariance matrix, eigenvalue, eigenvector, variance contribution rate, and cumulative variance contribution rate of each principal component are first calculated, as shown in Table 4.1. The results suggest the examination of cities for the first three principal components, which account for almost 70% of the total variability of the phenomenon, and the variance contribution rate of each factor is more than 14%.

**Table 4.1:** The eigenvalue, variance contribution rate, and cumulative variance contribution rate of principal components.

| **Principal components** | **C1** | **C2** | **C3** |
|---|---|---|---|
| **Eigenvalue** | 4.411235 | 2.632997 | 1.782743 |
| **Variance contribution rate** | 0.353679 | 0.211105 | 0.142935 |
| **Cumulative variance contribution rate** | 0.353679 | 0.564784 | 0.707719 |

Second, the load matrix of each factor is calculated to analyse the underlying meaning of the principal components by recognising each variable's contribution to each principal component. An analysis of the principal component characteristics in Table 4.2 demonstrates that digital inclusion and privacy have high factor loads on the first factor with a 35% variance contribution, reflecting the impact of digital inclusion and data protection rather than the technology itself. Thus, $C_1$ is considered a digital inclusion and data privacy factor.

Innovation, business sophistication, and civil society participation score highest in the second principal component, with a variance contribution rate of 21%, reflecting the economy's spirit of innovation and participatory engagement. Consequently, $C_2$ is referred to as the innovation factor. In a similar vein, waste treatment, environmental technologies and culture have a high load on the third factor with a 14% contribution of variance, reflecting the importance of green technology in

addition to the availability of an innovative community. The third principal component is referred to herein as the environment-community factor.

The variance contribution rate of each principal component is calculated as the weight for the weighted average calculation, and the smart city index can be obtained as:

$$\text{SMART INDEX} = 0.353679\ C_1 + 0.211105\ C_2 + 0.142935\ C_3$$

Third, the cities' static score and ranking of the three principal components of urban smartness are calculated to examine how cities have performed on average over the period 2005-2019. The results are shown in Table 4.3.

**Table 4.2:** Factor loading matrix.

| Factor | C1 | C2 | C3 |
|---|---|---|---|
| **ICT Infrastructure** | 0.176924 | 0.213756 | -0.1979 |
| **ICT Usage** | 0.07985 | 0.128027 | -0.06267 |
| **Privacy** | **0.544086** | -0.29864 | -0.06142 |
| **Digital inclusion** | **0.616783** | -0.33058 | -0.09892 |
| **Infrastructure** | 0.223866 | 0.215072 | -0.01682 |
| **Renewable energy** | 0.098179 | 0.02944 | 0.285871 |
| **Waste treatment** | 0.181952 | 0.066475 | **0.442845** |
| **Technology in Env.** | 0.133837 | 0.059055 | **0.416946** |
| **Education** | -0.00316 | 0.116924 | 0.155476 |
| **Creativity** | 0.059607 | -0.00458 | **0.417183** |
| **Digital Skills** | 0.152129 | 0.263865 | -0.0673 |
| **Gov. Effectiveness** | 0.004126 | 0.290791 | -0.33589 |
| **E-Gov.** | 0.223696 | 0.239439 | -0.20481 |
| **E-Participation** | 0.209966 | 0.154163 | -0.21468 |
| **Civil Society participation** | 0.120032 | **0.382911** | 0.218986 |
| **Innovation** | 0.16903 | **0.305372** | 0.100984 |
| **High-tech Emp.** | 0.040682 | 0.18914 | -0.10857 |
| **Entrepreneurship** | 0.088262 | -0.01873 | 0.111047 |
| **Business Sophistication** | 0.16903 | **0.305372** | 0.100984 |

The results of the first principal component demonstrate that Frankfurt, Washington, Los Angeles, Reykjavik, and Munich have the highest scores, indicating that they are the most advanced in digital inclusion, cybersecurity, and privacy, while Warsaw, Prague, and Bratislava rank lower than any other city. Given this, the former cities are more successful than others in closing the digital divide gap. While the EU is the most developed in terms of data protection laws, Germany is a trailblazer in data protection, enforcing stricter laws than many other countries (Custers et al., 2018). Similarly, Icelandic data privacy law is significantly rigorous and imposes high security and confidentiality requirements. On the other hand, there is still no comprehensive federal law in the USA that regulates data protection. However, California has the most developed state data privacy legislation.

So far, few cities have developed strategies and expertise to reduce the digital divide. Cities should develop agendas and learn from peers to drive frameworks that can bridge the digital divide, which is critical to the success of smart city implementation. The ranking of the second principal component shows that innovation, business sophistication and civic participation in Copenhagen, Helsinki, Stockholm, Zurich, and Oslo are remarkably better than in other cities, particularly Milan, Tallinn, and Bratislava, which ranked the worst among the cities. Therefore, fostering innovation capacities and prioritising research and development investments with citizen involvement is very important to improve readiness for the smart city transition.

The third principal component places Frankfurt, Munich, and Warsaw in the top three, along with Berlin and Bratislava as the five most developed cities regarding green technologies and innovative communities. Sydney, Melbourne, and Montreal's rankings are relatively low, suggesting that these cities have not paid enough attention to integrating green technologies into urban infrastructure. Therefore, these cities need to integrate green technologies into their smart city development and build the innovative capacity of their communities. Figure 4.8 shows the projection of the cities onto the principal components.

**Table 4.3:** Static scores and ranking of urban smartness.

| | C1 | Rank | C2 | Rank | C3 | Rank |
|---|---|---|---|---|---|---|
| **Amsterdam** | 0.686383 | 9 | 0.208795 | 14 | -0.12438 | 18 |
| **Barcelona** | -0.59019 | 30 | 0.043462 | 24 | -0.26175 | 25 |
| **Berlin** | 0.65049 | 11 | 0.2994 | 11 | 0.288945 | 4 |
| **Bratislava** | -0.96602 | 33 | -0.52508 | 31 | 0.242872 | 5 |
| **Brisbane** | 0.523317 | 15 | 0.057429 | 22 | -0.35296 | 29 |
| **Brussels** | -0.46125 | 27 | 0.356469 | 10 | -0.04566 | 12 |
| **Copenhagen** | -0.15657 | 21 | 1.152393 | 1 | -0.09935 | 16 |
| **Dublin** | -0.57551 | 28 | 0.165733 | 17 | -0.00327 | 10 |
| **Frankfurt** | 1.031867 | 1 | 0.25323 | 13 | 1.476243 | 1 |
| **Helsinki** | -0.17232 | 22 | 1.080681 | 2 | -0.11274 | 17 |
| **London** | 0.495755 | 18 | 0.030831 | 25 | -0.24844 | 23 |
| **Los Angeles** | 0.903267 | 3 | 0.73562 | 7 | -0.06896 | 15 |
| **Madrid** | -0.57739 | 29 | 0.14949 | 18 | -0.24845 | 24 |
| **Manchester** | 0.589809 | 14 | 0.044234 | 23 | -0.04731 | 13 |
| **Melbourne** | 0.511699 | 16 | 0.205282 | 15 | -0.45601 | 32 |
| **Milan** | 0.20874 | 20 | -0.69069 | 33 | 0.13859 | 8 |
| **Montreal** | 0.648255 | 12 | 0.090578 | 20 | -0.41546 | 31 |
| **Munich** | 0.819186 | 5 | 0.260163 | 12 | 0.903808 | 2 |
| **New York** | 0.807792 | 6 | 0.4123 | 9 | -0.23496 | 21 |
| **Oslo** | -0.27058 | 24 | 0.846719 | 5 | -0.06606 | 14 |
| **Paris** | 0.700526 | 8 | -0.10515 | 27 | -0.28616 | 26 |
| **Prague** | -0.79171 | 31 | -0.14049 | 28 | 0.220999 | 7 |
| **Reykjavik** | 0.879997 | 4 | -0.3997 | 29 | -0.20296 | 20 |
| **Stockholm** | -0.179 | 23 | 0.933815 | 3 | -0.15246 | 19 |
| **Sydney** | 0.509575 | 17 | 0.191785 | 16 | -0.46969 | 33 |
| **Tallinn** | 0.80082 | 7 | -0.67529 | 32 | -0.24504 | 22 |
| **Tokyo** | 0.481877 | 19 | 0.145161 | 19 | -0.30014 | 27 |
| **Toronto** | 0.635066 | 13 | 0.07513 | 21 | -0.41207 | 30 |
| **Vancouver** | 0.657745 | 10 | 0.016489 | 26 | -0.32937 | 28 |
| **Vienna** | -0.42435 | 26 | 0.588424 | 8 | -0.014 | 11 |
| **Warsaw** | -0.87294 | 32 | -0.42123 | 30 | 0.294688 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Washington** | 1.024813 | 2 | 0.840479 | 6 | 0.230183 | 6 |
| **Zürich** | -0.29722 | 25 | 0.864448 | 4 | 0.0628 | 9 |

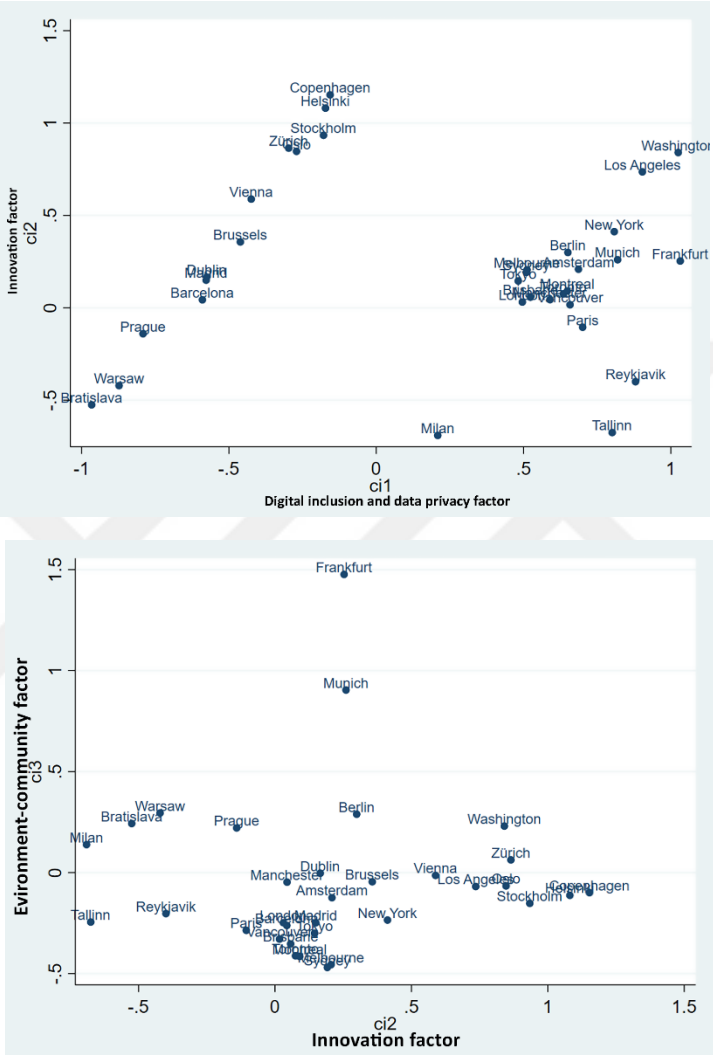



**Figure 4.8:** Projection of cities on the first two principal components and the second two principal components.

In order to study the dynamics stimulating the changes in smartness that occurred in each city from 2005 to 2019, the dynamic scores were calculated as given in Tables B.1 to B.3 in Appendix B and the trajectories that cities have followed over time with respect to each of the principal components are shown in Figures 4.9 to 4.11.

The dynamic scores related to the first component show that most cities have embarked on a steady trajectory over the past 15 years, indicating slow improvement in privacy laws and digital inclusion practices. The few exceptions include London,

Madrid, and Tallinn, which have shown an increasing trend over the past five years, and Barcelona, Dublin, Frankfurt, Milan, and Sydney over the past ten years, while Manchester, Stockholm, and Copenhagen have shown a fluctuating trend.

It can be noted that cities that are at the forefront, like Frankfurt, or those that are improving, are mainly European cities that have data protection laws in place, including the EU Data Protection Directive and its subsequent regulation, the General Data Protection Regulation. The different scores reflect that actual protection is based not only on the legal framework but on actual implementation and enforcement in each city (Custers et al., 2018). It is, therefore, important that cities learn from the experiences, practises, and decisions of other cities to develop an appropriate framework for data protection. Additionally, high-scoring cities that improve their digital inclusion are influenced by their high English proficiency, high GDP per capita, affordable mobile plans, and strong e-government programmes.

The trend described by the cities in relation to the second component highlights an increasing trend for Amsterdam, Barcelona, Dublin, Madrid, Prague, Sydney, Tallinn, Vienna, and Zurich, indicating an increase in their rate of innovation. These cities are generally well-positioned in terms of innovation and have fertile innovation ecosystems that include an encouraging policy environment and infrastructure, availability of academics and scientists, great capacity for attracting talent, university-industry collaborations, and large multinationals Companies that are leaders in their industries along with a network of small and medium-sized enterprises striving for innovation.

In contrast, London, Manchester, Stockholm, Montreal, Toronto, Vancouver, and New York show a declining trend, while Copenhagen and Milan experienced a fluctuating trend. These cities lag in terms of innovation and business sophistication, which are fundamental to the development of smart cities. The bottlenecks that hamper innovation capacity can have multiple causes, depending on the city's context. For example, Brexit not only had a negative impact on UK competitiveness through product and financial markets and market size (Sala-i-Martín, 2016) but also through innovation. While the United States is an innovation powerhouse, its innovation ecosystem is stuttering. This trend may be due to the decoupling of corporate activities from academic research, where data shows that total corporate R&D has fallen from around 30% in 1985 to below 20% in 2015 (Arora et al., 2020).

The trajectories associated with the third component show a more pronounced and increasing trend for Amsterdam, Bratislava, London, Los Angeles, Manchester, Montreal, New York, Paris, Reykjavik, Stockholm, Tallinn, Toronto, Vancouver, and Washington. These cities are implementing progressive environmental policies and plans, such as the EU Green Deal, continuously investing in green alternatives, retrofitting buildings to become more energy efficient like Vancouver, adopting a climate budget and promoting green tech start-ups.

Yet, the scores for Frankfurt, Milan, Munich, and Prague present a downward trend. These cities need to better manage the transition to greener energy and encourage technological innovation. In addition, they should mainstream environmental considerations into their strategic policymaking.




**Figure 4.9**: Trajectories over time (2005–2019) of cities with respect to the first principal component of DFA on the drivers of smart cities (The horizontal axis represents time; the vertical axis represent the city).




**Figure 4.10:** Trajectories over time (2005–2019) of cities with respect to the second principal component of DFA on the drivers of smart cities.




**Figure 4.11:** Trajectories over time (2005–2019) of cities with respect to the third principal component of DFA on the drivers of smart cities.

The smart scores and rankings are determined using the dynamic assessment model of urban smartness (Table 4.4), and the spatial distribution structure is shown in Figure 4.12. Overall, urban smartness has changed significantly over the past 15 years, but the smartness of most individual cities in the study has either steadily improved or remained constant. Smart practices vary significantly in each city, with Frankfurt, Washington, Munich, Los Angeles, and New York showing relatively strong urban smartness compared to the poor performance of Bratislava, Warsaw, and Prague.

It should be noted that US and German cities are at the top of the list with their cutting-edge smart city practices. Cities in the United States are becoming increasingly digitised and have made significant progress in broadband, e-services, e-participation, sensor-based information, Big Data, and interdependence with other public and private data sources. The city of New York, for example, offers free public Wi-Fi, easy access to city services, device charging, user-friendly mobile apps, and comprehensive government services, among others. In addition, the city has introduced many smart initiatives and strategies to manage waste and water, improve air quality and enhance public transport. These include increasing recycling rates, retrofitting lighting LED, recovering organic material from landfills, and introducing Active Transit Signal Priority. More importantly, internet access for Americans has increased from 52% in 2000 to 84% in 2015 (Perrin and Duggan, 2015).

In fact, over the past decade, the Obama administration has awarded several grants in addition to the National League of Cities incentives to encourage experimentation, entrepreneurship, and urban prototyping (Baykurt and Raetzsch, 2020). Nevertheless, large tech companies, such as IBM and Cisco are leading this development by providing municipalities with new technologies, data analytics and capital investments. Consequently, the development of smart cities in the US follows a bottom-up approach, where most smart city initiatives are driven by local governments, businesses, and public-private collaborations rather than directly funded by the federal government. Furthermore, the US has a participatory governance structure that involves various stakeholders, including citizens, in the development of its smart cities (Hu and Zheng, 2021).

In contrast to the industry-led initiatives in the US to implement smart cities, Europe has pursued a Living Lab model. Munich, in particular, is an important hub for advanced technologies in Germany due to its high investment in R&D activities and

ability to translate knowledge into innovation and, thus, value creation (De Prato and Nepelski, 2014).

Munich's smart city strategy, created in 1998, focused more on urban sustainability. It includes the use of ICT for the transformation into a post-carbon economy, decoupling the economy from resource consumption and improving economic competitiveness and citizens' quality of life. Munich's smart city strategy is led by the city government with a citizen-centred approach, involving citizens in designing and implementing strategies and initiatives. Munich has succeeded in aligning private and public sector interests and empowering businesses and knowledge institutions to shape policy (Gasco-Hernandez et al., 2022). In addition, an innovative ecosystem has been developed through collaboration between universities, corporate research and development departments, trade unions and different levels of government. Finally, the regressions over time for each smart city driver show that all of these drivers are significant, with most drivers showing a slight improvement over time (Table 4.5).

**Table 4.4:** Smart cities scores and ranks.

| City | Smart score | Rank | City | Smart score | Rank |
|---|---|---|---|---|---|
| Amsterdam | 0.269058753 | 7 | Munich | 0.473836163 | 3 |
| Barcelona | -0.236975862 | 30 | New York | 0.339153851 | 5 |
| Berlin | 0.334569838 | 6 | Oslo | 0.073606258 | 24 |
| Bratislava | -0.417793332 | 33 | Paris | 0.18466137 | 12 |
| Brisbane | 0.14675955 | 19 | Prague | -0.278080933 | 31 |
| Brussels | -0.094408271 | 27 | Reykjavik | 0.197847547 | 9 |
| Copenhagen | 0.173700336 | 14 | Stockholm | 0.112033056 | 21 |
| Dublin | -0.169026029 | 28 | Sydney | 0.153577809 | 17 |
| Frankfurt | 0.629414173 | 1 | Tallinn | 0.105651076 | 22 |
| Helsinki | 0.151077206 | 18 | Tokyo | 0.158173606 | 16 |
| London | 0.146336002 | 20 | Toronto | 0.181570726 | 13 |
| Los Angeles | 0.464903109 | 4 | Vancouver | 0.189033076 | 10 |
| Madrid | -0.208164655 | 29 | Vienna | -0.027865248 | 25 |
| Manchester | 0.211178819 | 8 | Warsaw | -0.355543295 | 32 |
| Melbourne | 0.159133659 | 15 | Washington | 0.572785581 | 2 |
| Milan | -0.052172143 | 26 | Zürich | 0.086345501 | 23 |

| | | |
|---|---|---|
| Montreal | 0.189012006 | 11 |

**Table 4.5:** Regression coefficients of the simple regression models where each smart city driver is regressed with respect to time (2005 to 2019).

| Variables | Coef. | Adj R2 |
|---|---|---|
| ICT Infrastructure | 0.0266492*** | 0.9493 |
| ICT Usage | 0.0405416*** | 0.9209 |
| Infrastructure | -0.0071831*** | 0.8337 |
| Renewable energy | 0.0059469*** | 0.996 |
| Waste treatment | -0.0005126*** | 0.5406 |
| Technology in Env. | -0.0008632*** | 0.7759 |
| Education | 0.016299*** | 0.9684 |
| Creativity | -0.0007834*** | 0.6185 |
| Digital Skills | 0.0119228*** | 0.6824 |
| Gov. Effectiveness | -0.0045092*** | 0.9192 |
| E-Gov. | 0.0173334*** | 0.7004 |
| E-Participation | 0.0320786*** | 0.8718 |
| Civil Society participation | -0.0055401*** | 0.511 |
| Innovation | 0.0015371** | 0.2992 |
| High-tech Emp. | 0.0061817*** | 0.9716 |
| Entrepreneurship | 0.0026569*** | 0.7544 |
| Business Sophistication | 0.0039984** | 0.343 |
| Privacy | - | - |
| Digital inclusion | - | - |
| * Significance at 10 %; **at 5 %; ***at 1 % | | |

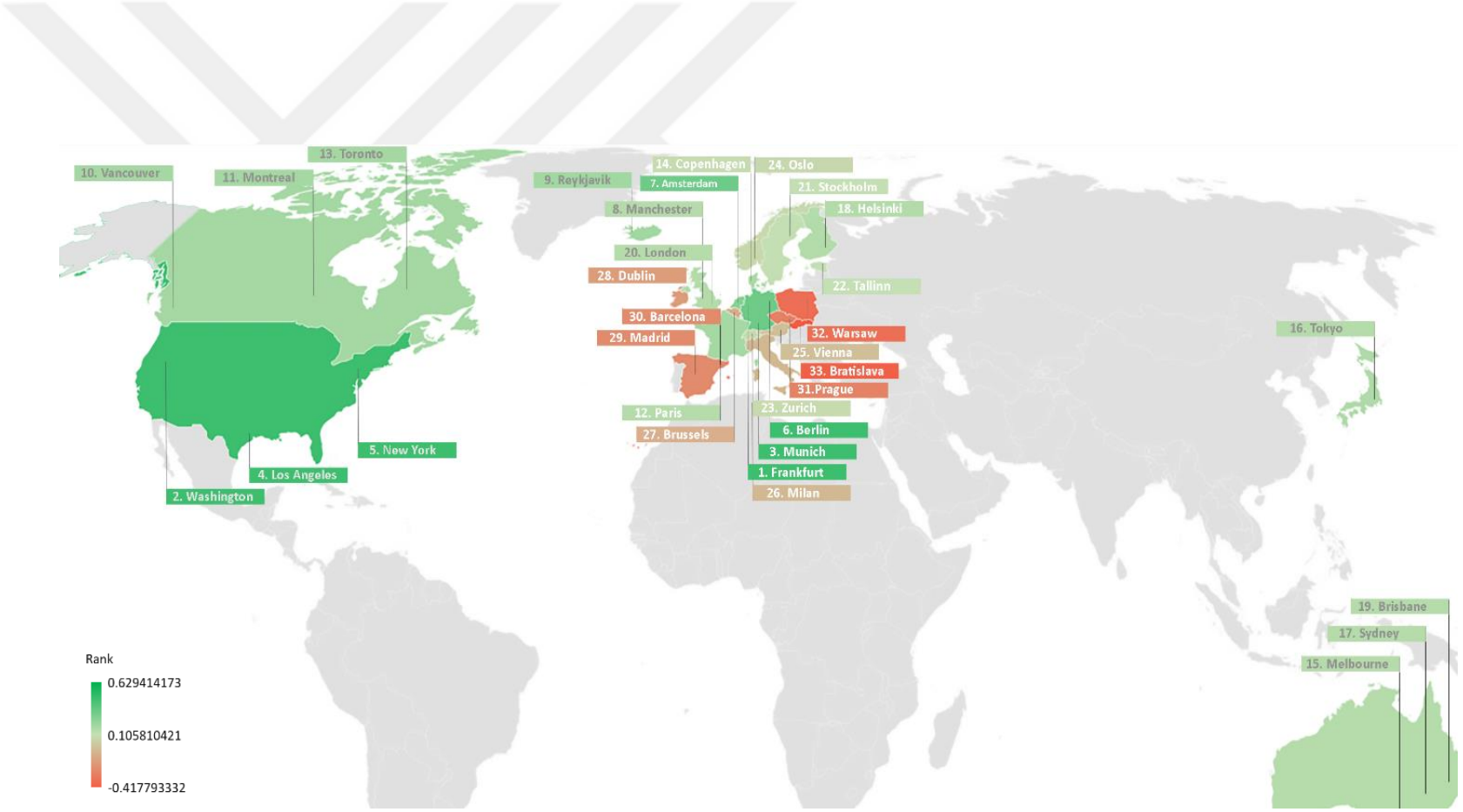



**Figure 4.12:** Spatial distribution of smart scores of urban smartness of cities.

## 4.3. Results And Discussions Of Panel Var Analysis (Does Smart Governance Of Smart City Drivers Achieve Urban Sustainability?)

To investigate the relationship between the systemic governance of smart city drivers and urban sustainability, a comprehensive literature review was conducted to pin down the smart city drivers and indicators of urban sustainability. Table 4.6 presents the descriptive statistics on the variables of the study. The results of the econometric analysis of Models 2 and 3 are provided in Appendix C.

**Table 4.6:** Descriptive statistics, 2009-2019.

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Technology (TECH) | 390 | 5.553739 | 0.835264 | 3.023333 | 6.933333 |
| Governance (GOV) | 390 | 4.892177 | 0.623122 | 3.441275 | 6.028496 |
| Community (COM) | 390 | 4.411653 | 0.85156 | 2.280798 | 6.491787 |
| Innovative Economy (IECO) | 390 | 3.717886 | 0.7664191 | 2.025709 | 5.945 |
| Economic Sustainability (GNI) | 390 | 52.17154 | 17.34929 | 12.6 | 95.97 |
| Environmental Sustainability (CO2) | 390 | 8.88477 | 3.489196 | 3.405038 | 19.46926 |
| Social Sustainability (SOC) | 390 | 6.02703 | 0.453385 | 3.928 | 6.801494 |
| GDP in Services (GDPSER) | 390 | 63.06477 | 6.669681 | 41.33593 | 77.52413 |
| Population Density (DEN) | 390 | 946.1913 | 1023.683 | 2.95994 | 3757 |
| GDP growth (GDPG) | 390 | 2.717901 | 3.966647 | -15.6256 | 34.11373 |

Next, the Pesaran test for cross-section interdependence is performed. The results are shown in Table 4.7. The null hypothesis of cross-sectional independence is rejected for all the variables in question, indicating the existence of interdependence between the cross-sections. Consequently, the second-generation unit root test is used to test the stationarity of the data. Table 4.8 shows the results of the Pesaran

unit root test for level and first difference. According to the CIPS statistics, the variables have a mixed order of integration, with GDP growth stationary at level and the remaining variables stationary at the first difference.

**Table 4.7:** Cross-sectional independence test, 2009-2019.

| Variable | CD-test | p-value | average joint T | mean ρ | mean abs(ρ) |
|---|---|---|---|---|---|
| GNI | 35.542 | 0.0000 | 15 | 0.51 | 0.66 |
| Technology | 50.471 | 0.0000 | 15 | 0.72 | 0.82 |
| Governance | 19.968 | 0.0000 | 15 | 0.29 | 0.58 |
| Community | 40.454 | 0.0000 | 15 | 0.58 | 0.67 |
| Innovative economy | 8.62 | 0.0000 | 15 | 0.12 | 0.45 |
| GDP in services | 38.317 | 0.0000 | 15 | 0.55 | 0.59 |

**Table 4.8**: Pesaran panel unit root test (CIPS), 2009-2019.

| Variable | CIPS (Level) | CIPS (First difference) |
|---|---|---|
| Technology | -1.549 | -2.932* |
| Community | -2.182 | -3.49* |
| Governance | -1.692 | -2.809* |
| Innovative economy | -1.759 | -3.226* |
| GNI | -1.552 | -3.231* |
| CO2 | -2.047 | -3.373* |
| Social sus. | -2.057 | -4.797* |
| GDP in services | -1.859 | -3.183* |
| GDP growth | -3.082* | NA |
| Population density | -0.43 | -2.742** |
| Critical values at | 10% 5% 1% | |
| | -2.07 -2.17 -2.34 | |

Note: *, **, and *** indicate rejection of the null hypotheses at 1%, 5%, and 10% levels, respectively.

Having established the data's stationarity, the variables' cointegration is tested according to Westerlund (2007). Westerlund cointegration test allows for a large degree of heterogeneity, both in the long-run cointegrating relationship and in the short-run dynamics, and dependence within as well as across the cross-sectional units (Persyn and Westerlund, 2008). The results in Table 4.9 show that the null

hypothesis cannot be rejected and that there is no cointegration relationship between the variables. Therefore, we proceed with the estimation of the PVAR model. To determine the number of lags used in the specified VAR model, we follow the selection criteria of Andrews and Lu (2001), which minimise MBIC, MAIC and MQIC, respectively (Table 4.10). Accordingly, the first-order panel VAR is selected using the first four lags of the endogenous variables as instruments. Given the large number of cities (N) and the short time period (T), where N > T, GMM model estimation is suitable for maximising the number of observations used for inference and obtaining consistent estimates. Before estimating the model, we check the stability of the model, which is important to confirm the reliability of the analysis. Indeed, all the values presented in Table 4.11 are less than 1, while the points in Figure 4.13 lie within the unit circle.

**Table 4.9:** Westerlund test for cointegration, 2009-2019.

| | | |
|---|---|---|
| Ho: No cointegration | Number of panels= 26 | |
| Ha: Some panels are cointegrated | Number of periods= 15 | |
| **Variance ratio** | **Statistic** | **p-value** |
| | 0.5820 | 0.2803 |

**Table 4.10:** Lag selection, 2009-2019.

| lag | CD | J | J pvalue | MBIC | MAIC | MQIC |
|---|---|---|---|---|---|---|
| **1** | 1.0000000 | 136.7368 | 0.653926 | -664.001 | -151.263 | -357.391 |
| **2** | 1.0000000 | 102.262 | 0.63757 | -498.292 | -113.738 | -268.334 |
| **3** | 0.9999999 | 71.15558 | 0.505983 | -329.214 | -72.8444 | -175.908 |
| **4** | 0.9999998 | 42.54152 | 0.21007 | -157.643 | -29.4585 | -80.9904 |

**Table 4.11:** Stability test of PVAR model.

| **Eigenvalue** | | **Modulus** |
|---|---|---|
| Real | Imaginary | |
| 0.873057 | 0 | 0.873057 |
| 0.515698 | -0.1725 | 0.543785 |
| 0.515698 | 0.172504 | 0.543785 |
| 0.389808 | 0 | 0.389808 |

| | | |
|---|---|---|
| -0.07414 | -0.12198 | 0.142745 |
| -0.07414 | 0.121982 | 0.142745 |

The results of the specified panel VAR model are shown in Table 4.12. The specified panel VAR model fails to reject Hansen's overidentification restriction because Hansen's J chi2 equals 122.64 (p = 0.159), indicating that all instruments in the model are valid. Based on the statistical significance of the parameters, we can conclude that income level is positively correlated with the previous levels and that higher-income cities have higher levels of ICT infrastructure and use, better institutions, an educated and creative community, as well as an innovative economy (Technology, Governance, Community and Economy are statistically significant at the 1% level and positively associated with GNP).

In detail, the use and adaptation of technology is expected to positively impact national income as investment in ICT increases productivity, improves industrial structure, creates new digital industries, and improves finance by reducing information asymmetries, thus facilitating sustainable economic development. This finding is supported by many other empirical studies (Yao et al., 2020; Irawan, 2014; Cortes and Navarro, 2011).

Additionally, the significant and positive impact of governance on national income is also an expected result and an indication that governance effectiveness, quality, lower bureaucracy, active citizen participation and the use of technology in public administration are crucial for economic sustainability, which is consistent with the findings of Giuliodori et al. (2022). The positive influence of a smart community on economic development due to its impact on the rate of technological innovation produced is also confirmed by endogenous growth theories that emphasise the role of human capital (Mankiw et al., 1992; Lucas, 1988; Romer, 1990). Likewise, an innovative economy that leverages innovation and technologies establishes cooperation between institutions, companies, citizens, and research organisations, and develops new models of consumption, production, and distribution has a positive impact on economic development, as Galperina et al. (2016) and Derlukiewicz (2014) have found.

The results of Model 2 show that carbon emissions are positively correlated with its previous levels and that cities with higher levels of ICT infrastructure and use, better institutions and an educated and creative community are environmentally

sustainable (Technology, Governance and Community are statistically significant at the 1% level and negatively associated with $CO_2$). In contrast, $CO_2$ emissions are negatively affected by an innovative economy. Specifically, green technologies, such as smart meters, electricity grids, and real-time monitoring of urban resources and consumption improve environmental performance, which is also confirmed by the findings of Wang and Zhou (2022) and Zhu and Lu (2022).

Furthermore, smart governance can have a positive impact on the environmental quality of a city through environmental legislation, green space management, citizen participation and the promotion of behavioural change to protect the environment, among other things - in contrast to the findings of Giuliodori et al. (2022), who found no significant relationship between these two factors. The impact of a smart community on the environment is also expected, as smarter communities have high environmental awareness, are willing to buy greener products or pay for a cleaner environment, and advocate for environmentally friendly laws that reduce pollution in the city. Conversely, an innovative economy increases $Co_2$ emissions, possibly because companies focus exclusively on profitable opportunities rather than on environmental issues or on developing new production capacities that require higher inputs of production factors, including energy and other natural resources, and higher emission rates.

Finally, the results of Model 3 indicate that social sustainability is significantly and positively influenced by its lagged value, governance, community, innovative economy and GDP growth, and negatively by technology. In this regard, smart governance promotes social sustainability through the provision of efficient public services to citizens, the creation of more interdisciplinary opportunities in the economy, and the use of the bidirectional flow of information and services between the government and citizens, which enhances the ability of the administration to find solutions to citizens' challenges. A smart community also promotes social sustainability, as educated people with digital skills are less likely to be digitally excluded, unemployed or suffer from poverty compared to uneducated people.

Moreover, the innovative economy promotes social sustainability by creating new employment opportunities, thereby increasing incomes, and providing innovative products and services at affordable prices that enhance the purchasing power of citizens and improve living standards (Govindarajan and Ramamurti, 2011). On the other hand, negative impacts of technology on social sustainability are expected when

the benefits of ICT are unevenly distributed, when digital innovation tends to marginalise citizens and when intensive use of technology causes potential physiological problems.

**Table 4.12:** PVAR (1 lag) model, 2009-2019.

| | Coef. | Std.Err. | z | P>z | [95%Conf. | Interval] |
|---|---|---|---|---|---|---|
| **GNI** | | | | | | |
| GNI L1. | 0.444* | 0.052 | 8.490 | 0.000 | 0.342 | 0.546 |
| Technology L1. | 1.206* | 0.403 | 2.990 | 0.003 | 0.417 | 1.996 |
| Governance L1. | 4.212* | 0.659 | 6.390 | 0.000 | 2.921 | 5.503 |
| Community L1. | 0.454* | 0.169 | 2.680 | 0.007 | 0.122 | 0.785 |
| Economy L1. | 4.024* | 0.713 | 5.640 | 0.000 | 2.627 | 5.422 |
| GDPservices L1. | -0.067 | 0.083 | -0.800 | 0.421 | -0.229 | 0.096 |
| **Technology** | | | | | | |
| GNI L1. | 0.012* | 0.004 | 2.840 | 0.005 | 0.004 | 0.021 |
| Technology L1. | 0.743* | 0.043 | 17.290 | 0.000 | 0.659 | 0.827 |
| Governance L1. | -0.072 | 0.062 | -1.170 | 0.244 | -0.193 | 0.049 |
| Community L1. | -0.026*** | 0.014 | -1.910 | 0.056 | -0.053 | 0.001 |
| Economy L1. | 0.204* | 0.039 | 5.260 | 0.000 | 0.128 | 0.280 |
| GDPservices L1. | 0.014** | 0.006 | 2.360 | 0.018 | 0.002 | 0.025 |
| **Governance** | | | | | | |
| GNI L1. | 0.007* | 0.002 | 2.850 | 0.004 | 0.002 | 0.012 |
| Technology L1. | 0.091* | 0.029 | 3.140 | 0.002 | 0.034 | 0.147 |
| Governance | 0.621* | 0.084 | 7.400 | 0.000 | 0.457 | 0.786 |

| | | | | | | |
|---|---|---|---|---|---|---|
| L1. | | | | | | |
| Community L1. | 0.003 | 0.013 | 0.240 | 0.811 | -0.022 | 0.028 |
| Economy L1. | -0.078* | 0.025 | -3.090 | 0.002 | -0.128 | -0.029 |
| GDPservices L1. | -0.004 | 0.005 | -0.910 | 0.364 | -0.014 | 0.005 |
| **Community** | | | | | | |
| GNI L1. | -0.023** | 0.012 | -1.870 | 0.062 | -0.047 | 0.001 |
| Technology L1. | 0.442* | 0.098 | 4.500 | 0.000 | 0.250 | 0.635 |
| Governance L1. | -0.268 | 0.184 | -1.450 | 0.146 | -0.630 | 0.093 |
| Community L1. | 0.583* | 0.091 | 6.430 | 0.000 | 0.405 | 0.760 |
| Economy L1. | -0.620* | 0.104 | -5.950 | 0.000 | -0.824 | -0.416 |
| GDPservices L1. | -0.005 | 0.013 | -0.390 | 0.693 | -0.031 | 0.021 |
| **Economy** | | | | | | |
| GNI L1. | -0.000 | 0.003 | -0.120 | 0.905 | -0.007 | 0.006 |
| Technology L1. | -0.028 | 0.029 | -0.980 | 0.329 | -0.084 | 0.028 |
| Governance L1. | 0.344* | 0.073 | 4.690 | 0.000 | 0.200 | 0.487 |
| Community L1. | 0.068* | 0.014 | 4.730 | 0.000 | 0.040 | 0.096 |
| Economy L1. | -0.186* | 0.045 | -4.170 | 0.000 | -0.274 | -0.099 |
| GDPservices L1. | -0.011** | 0.004 | -2.360 | 0.018 | -0.019 | -0.002 |
| **GDPservices** | | | | | | |
| GNI L1. | 0.054 | 0.040 | 1.350 | 0.177 | -0.024 | 0.131 |
| Technology L1. | 2.252* | 0.311 | 7.250 | 0.000 | 1.643 | 2.861 |
| Governance L1. | 0.779 | 0.474 | 1.640 | 0.100 | -0.151 | 1.709 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Community L1. | -1.529* | 0.160 | -9.540 | 0.000 | -1.843 | -1.215 |
| Economy L1. | 4.008* | 0.777 | 5.160 | 0.000 | 2.485 | 5.531 |
| GDPservices L1. | -0.059 | 0.044 | -1.330 | 0.183 | -0.146 | 0.028 |

Instruments: l(1/4).(GNI Technology Governance Community Economy GDPsevices).

Control variable: GDP from services.

*, **, *** indicate statistical significance with a 1%, 5%, 10% significance level, respectively.

Hansen's J chi2(108) = 122.64454 (p = 0.159)

To further investigate the relationships between variables, a PVAR Granger causality test is conducted to determine the causality of one variable to another. A block exogeneity analysis (ALL) confirms the presence of endogeneity. The results of the test, presented in Table 4.13, show that: (1) There is a bidirectional relationship between national income and technology, showing a feedback effect from economic wealth to technology, suggesting that cities with higher income levels have more resources to invest in ICT infrastructure and have a higher demand for technology and usage, creating new opportunities through electronic service delivery. This result is consistent with the findings of several studies, including Sarangi and Pradhan (2020) and Pradhan et al. (2021). (2) There is a bidirectional relationship between national income and governance, which means that economic sustainability influences urban governance and develops a citizen-centric and digital operating model for the city. (3) There is a bidirectional relationship between national income and community, which means that developed economies have higher levels of educated, creative and skilled citizens. (4) A unidirectional relationship exists between national income and the innovative economy.

The panel VAR Granger causality results for Model 2 suggest a unidirectional relationship between carbon emissions and governance, community, and innovative economy. At the same time, there is a bidirectional relationship between carbon emissions and technology. Finally, the Panel VAR Granger results of Model 3 indicate a bidirectional relationship between social sustainability and technology, governance, innovative economy, and GDP growth. There is also a unidirectional relationship between social sustainability and community. Figure 4.14 shows a visual summary of the results of the three estimated models.

**Table 4.13:** PVAR Granger causality, 2009-2019.

| Equation\Excluded | chi2 | df | Prob > chi2 |
|---|---|---|---|
| **GNI** | | | |
| Technology | 8.967* | 1 | 0.003 |
| Governance | 40.889* | 1 | 0 |
| Community | 7.205* | 1 | 0.007 |
| Economy | 31.84* | 1 | 0 |
| GDPservices | 0.647 | 1 | 0.421 |
| ALL | 95.105 | 5 | 0 |
| **Technology** | | | |
| GNI | 8.06* | 1 | 0.005 |
| Governance | 1.36 | 1 | 0.244 |
| Community | 3.661** | 1 | 0.056 |
| Economy | 27.708* | 1 | 0 |
| GDPservices | 5.559* | 1 | 0.018 |
| ALL | 48.982 | 5 | 0 |
| **Governance** | | | |
| GNI | 8.12* | 1 | 0.004 |
| Technology | 9.858* | 1 | 0.002 |
| Community | 0.057 | 1 | 0.811 |
| Economy | 9.546* | 1 | 0.002 |
| GDPservices | 0.823 | 1 | 0.364 |
| ALL | 38.843 | 5 | 0 |
| **Community** | | | |
| GNI | 3.491*** | 1 | 0.062 |
| Technology | 20.258* | 1 | 0 |
| Governance | 2.112 | 1 | 0.146 |
| Economy | 35.41* | 1 | 0 |
| GDPservices | 0.156 | 1 | 0.693 |
| ALL | 62.148 | 5 | 0 |
| **Economy** | | | |
| GNI | 0.014 | 1 | 0.905 |
| Technology | 0.952 | 1 | 0.329 |

| | | | |
|---|---|---|---|
| Governance | 21.96* | 1 | 0 |
| Community | 22.372* | 1 | 0 |
| GDPservices | 5.581** | 1 | 0.018 |
| ALL | 61.612 | 5 | 0 |
| **GDPservices** | | | |
| GNI | 1.822 | 1 | 0.177 |
| Technology | 52.5* | 1 | 0 |
| Governance | 2.698 | 1 | 0.1 |
| Community | 91.037* | 1 | 0 |
| Economy | 26.598* | 1 | 0 |
| ALL | 149.481 | 5 | 0 |

*, **, *** indicate statistical significance with a 1%, 5%, 10% significance level, respectively.

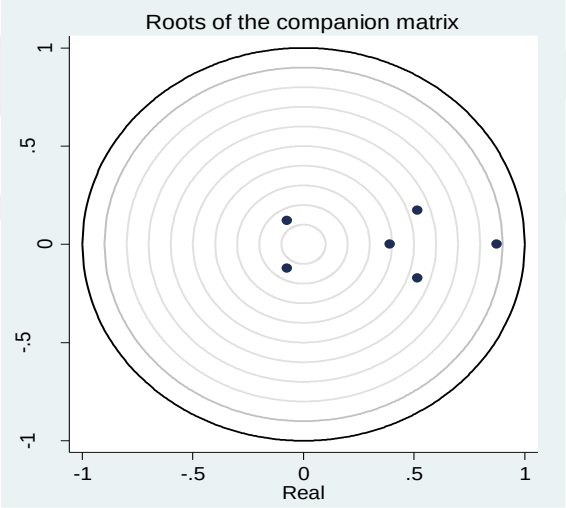



**Figure 4.13:** Stability condition of PVAR model.

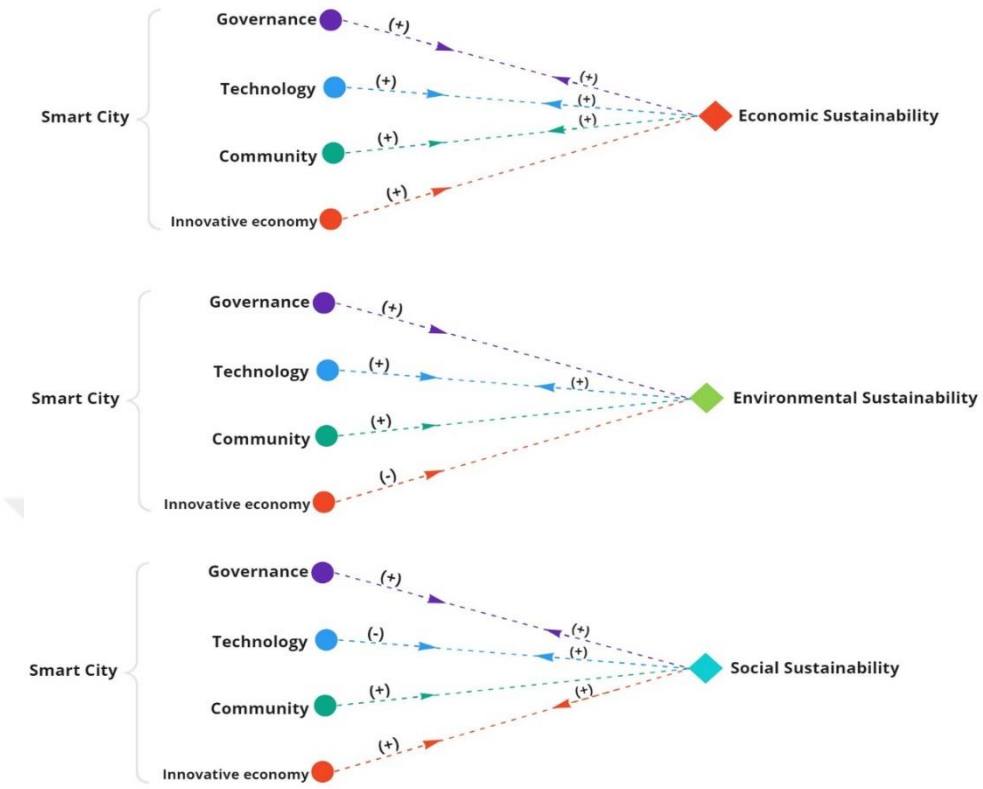



**Figure 4.14:** Relationships between analysed variables.

Finally, we estimate the variance decomposition and the impulse response function. The former is useful to show how much of the variance in the system is explained by changes/shocks in the respective covariates, while the latter indicates how a variable responds to a sudden change (shock) in a particular variable while holding other variables in the system constant.

An overview of the variance decomposition (see Table 4.14) shows that 7.41% of the variation in national income is explained by changes in the deployment and use of technology. In comparison, 11.35% is explained by changes in governance over a 10-year period. Analogously, changes in the community and innovative economy determine the fluctuations in national income by 2.57% and 6.67%, respectively.

Moreover, in Model 2, the growth rate of $CO_2$ emissions is explained by 6.89% variations in technology, 1.4% in governance, 3.72% in community and 15.97% in innovative economy. By the same token, in Model 3, 30.8% of the variance in social sustainability can be attributed to differences in technology, while 7.48% can be explained by variations in governance, 9.42% by differences in community, and 3.13% by variations in the economy.

**Table 4.14**: Variance decomposition, 2009-2019.

| Response Variable and Forecast horizon | Impulse variable | | | | | |
|---|---|---|---|---|---|---|
| | **GNI** | **Technology** | **Governance** | **Community** | **Economy** | **GDP services** |
| **GNI** | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.7607007 | 0.0352597 | 0.1077669 | 0.0255673 | 0.0676008 | 0.0031046 |
| 10 | 0.7173931 | 0.0741228 | 0.1134882 | 0.0252742 | 0.0666584 | 0.0030633 |
| **Technology** | | | | | | |
| 1 | 0.0022561 | 0.9977439 | 0 | 0 | 0 | 0 |
| 5 | 0.0392107 | 0.8425305 | 0.012677 | 0.0044618 | 0.0886209 | 0.012499 |
| 10 | 0.0546423 | 0.8006626 | 0.0393621 | 0.0040083 | 0.0903718 | 0.0109528 |
| **Governance** | | | | | | |
| 1 | 0.0480931 | 0.0013962 | 0.9505107 | 0 | 0 | 0 |
| 5 | 0.0500038 | 0.0579495 | 0.8774079 | 0.0007553 | 0.011357 | 0.0025264 |
| 10 | 0.0589643 | 0.1000736 | 0.8214929 | 0.0012863 | 0.0158156 | 0.0023672 |
| **Community** | | | | | | |
| 1 | 0.0546611 | 0.0006334 | 0.0354148 | 0.9092907 | 0 | 0 |
| 5 | 0.0363864 | 0.0966519 | 0.056345 | 0.7420378 | 0.0640781 | 0.0045007 |
| 10 | 0.0357643 | 0.1018892 | 0.0631126 | 0.7288507 | 0.0653938 | 0.0049895 |
| **Economy** | | | | | | |
| 1 | 0.0399666 | 0.0113175 | 0.0000735 | 0.0027968 | 0.9458455 | 0 |
| 5 | 0.0377566 | 0.0134883 | 0.0420464 | 0.0224791 | 0.8769486 | 0.0072811 |
| 10 | 0.0378921 | 0.0158178 | 0.0419957 | 0.0224427 | 0.8745546 | 0.0072972 |
| **GDPservices** | | | | | | |
| 1 | 0.0561134 | 0.0032851 | 0.0515526 | 0.001148 | 0.0124754 | 0.8754255 |
| 5 | 0.0513314 | 0.0221609 | 0.0651589 | 0.0718343 | 0.1510174 | 0.6384972 |
| 10 | 0.054201 | 0.030397 | 0.0763519 | 0.0700464 | 0.1478975 | 0.6211062 |

From the graphical representation of the impulse response function in Figure 4.15, we can conclude that a positive technology shock leads to a slight increase in national income, stabilising in the following periods. That is, technology has a positive impact on economic sustainability through improved productivity and resource efficiency (Yao et al., 2020). Further, in the current period, an initial significant

negative response of national income is observed when a positive shock is applied to governance or the innovative economy, followed by a significant positive response. This could be due to the time it takes citizens or businesses to adjust to smart governance, e-participation, and online services. Over time, citizens become accustomed to these services, which helps governments to deliver efficient services and thus achieve economic sustainability (Meijer and Bolívar, 2016). In contrast, a positive shock to the community leads to an initial increase in national income, which subsequently decreases and then stabilises. Indeed, human capital increases productivity and, thus, economic performance. However, insufficient demand for skilled labour can reduce the productivity of workers who work in jobs that do not match their education (McGowan and Andrews, 2017).

The impulse response function in Model 2 shows that a positive shock to technology, community or governance initially increases $Co_2$ emissions, then decreases, becomes negative and thereafter increases again and fluctuates towards zero, while in the case of a shock to the innovative economy, $Co_2$ emissions increase directly and stabilise in later periods. This means that environmental sustainability initially deteriorates while the economy and production adapt to the improved processes, which then improve environmental sustainability through ICT applications. However, profit-seeking companies undo the positive environmental impact of technology by consuming more resources and emitting more pollutants than before (Colding et al., 2020). In a similar vein, rent-seeking and corruption, such as accepting bribes to waive environmental regulations for polluting companies and enforcing legal provisions on the basis of kickbacks, undermine all ensuing environmental protections (Drazkiewicz et al., 2015). Moreover, qualified citizens are more likely to earn higher incomes, leading to higher consumption or purchasing goods that compromise environmental sustainability (Wang et al., 2020).

Finally, social sustainability shows an immediate decline, followed by a sharp increase, which later declines and subsides over time when there is a positive shock to technology, governance, or the innovative economy. Social sustainability declines as citizens embrace technology and smart governance, which prevents them from realising their potential. To the extent that citizens embrace new technologies and realise the benefits of smart governance and technologies, social sustainability will emerge (Meijer and Bolívar, 2016). However, overuse of technology, the digital divide (Van Winden and de Carvalho, 2017), excessive government interference, ineffective

citizen participation (Wang and Zhou, 2022) or unequal distribution of the benefits of an innovative economy may later compromise social sustainability.

In contrast, a shock acting on a community leads to a negative reaction in social sustainability, followed by an increase in the first period, which then decreases, only to become positive again and finally stabilise over time. This suggests that education or digital skills initially lead to inequality. However, when most citizens are highly educated and digitally literate, in the long run, social sustainability tends to improve.

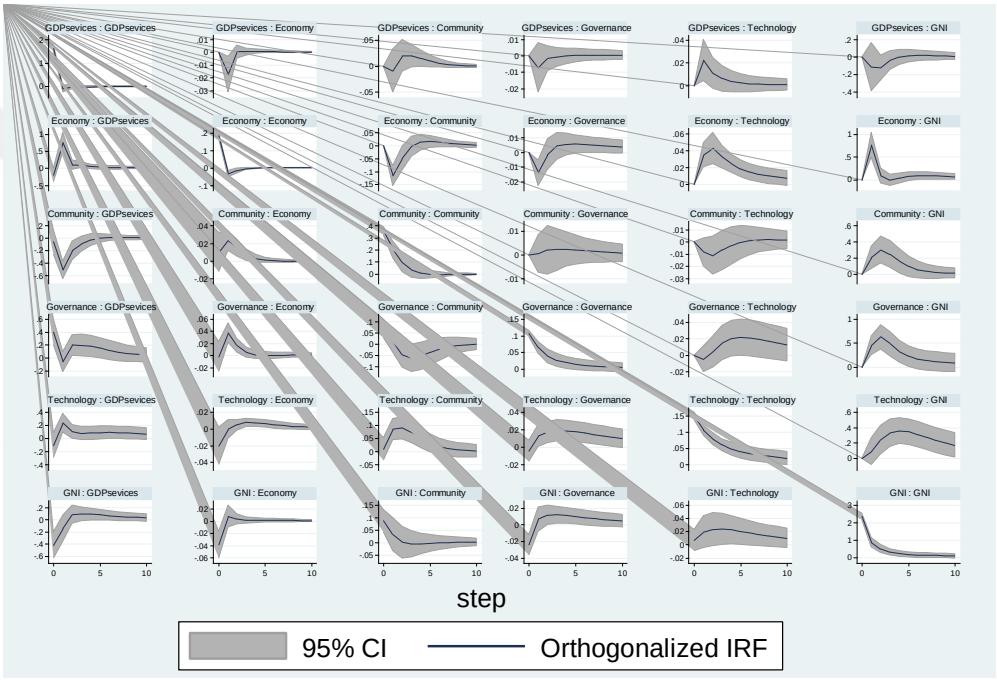



**Figure 4.15**: Impulse response function**,** 2009-2019.

The overall results are twofold. First, there is a systemic mode of governance of smart complementarities between smart city drivers and economic sustainability, as we have confirmed a unidirectional or bidirectional positive causal relationship between all smart city drivers and economic sustainability. In other words, a mutually reinforcing relationship exists between technology, governance, community, and innovative economy to promote economic sustainability. Second, there is a fragmented governance mode that fails to coordinate smart and negative complementarities to achieve environmental and social sustainability. In other words, technological progress takes place in an uncoordinated and bottom-up approach that further complicates urban systems and hinders achieving their sustainability goals.

# CHAPTER FIVE
# POLICY IMPLICATIONS

## 5.1. What Tools/ Approaches Might Governments Use To Promote Smart Cities?

In response to the growing demand for implementing smart city agendas worldwide, understanding the complexities and interactions of smart city drivers and outcomes has become imperative for policymakers to better address urban challenges and adopt more integrated policies. The study contributes to theory by capturing the drivers, desired outcomes, and negative externalities of smart cities in a novel way in a new framework based on network analysis. The findings of this study suggest the need for an alternative methodology for rethinking the available frameworks, first by breaking down the complexity of the smart city system and second by highlighting the potential synergies and trade-offs among the smart city indicators. Underlying is that identifying top indicators in accordance with the results of the network analysis can enable policymakers, city planners, and governments working to implement smart cities first to establish the skeleton of smart cities as per the priorities in establishing smart cities and then organise the remaining parts in tune with the top indicators.

The findings emphasise the importance of innovation and business sophistication in promoting the transition to smart cities. Therefore, policymakers should pledge to increase private and public R&D expenditure, boost industry-university collaborations, and embed innovation strategies into every aspect of urban life. Given the importance of ICT in developing smart city initiatives, ICT implementation must be manifold, including the multidimensionality of the smart city. These technological projects, which are part of the transformation of cities, are often developed by private corporates that generate enormous amounts of data and knowledge that entrepreneurs further leverage. Therefore, an enabling environment for businesses and start-ups is critical for the successful implementation of smart cities. In addition, policymakers need to incorporate the e-government in their development perspectives as it offers efficient public services, better access and participation, and increased transparency and accountability of government. More importantly, policymakers should consider the quality of institutions as core to their smart city strategies. In particular, government effectiveness will enable the innovative

and efficient use of ICT infrastructure and ensure the digital inclusion of citizens to tackle the complexity of the numerous challenges and achieve smart city goals.

Furthermore, the study implies that policymakers should consider the synergies and trade-offs between certain policies rather than implementing a welter of inharmonious policies. This means that policymakers should align policies to achieve an intended (first-best) outcome (if a synergy exists). Otherwise, the policy would be counterproductive (if there is a trade-off). For instance, digitalisation improves productivity growth and government transparency, among other things, but exacerbates inequality. Here we recognise that this driver will lead to conflicting outcomes, which should be balanced by parallel measures to eliminate the negative outcome.

This study not only serves as a policy tool but also provides new insights that can be used to enhance the productivity and efficiency of smart city systems and develop innovative methods and new ways to improve their performance.

In terms of implications for the research community, this study provides a steppingstone for further work on the interrelationships among smart city indicators. In particular, researchers can use the network analysis results to examine the cascading or inhibiting effects of policy interventions on individual drivers. Moreover, the existence of a trade-off could be a mainstay for an in-depth analysis of how to eliminate such negative consequences. More importantly, there is an urgent need for interdisciplinary research and collaboration among academics from different disciplines in the field of smart urban development. This is due to the insufficient and incomprehensive understanding of how the various components, dimensions, and indicators function in the context of a smart city framework. Comprehensive research is needed to fill this gap that has the potential to bring together all systems and actors in the city in the analysis.

### 5.2. How Might Governments Develop Smarter Cities?

The city ranking is an important empirical tool for reporting comparative advantages and city-specific features, which can serve as strategic policy advice for urban development. In this comparative study, cities are evaluated and ranked in terms of various smart drivers including technology, community, infrastructure, community, and governance, to reveal the best (and worst) places in terms of their urban smartness.

The results of this study can inform stakeholders about potential improvements to implement smart drivers more efficiently and effectively and lead cities towards smartness. Lower-ranked cities like Warsaw, Bratislava and Prague need to address digital inclusion and data privacy to avoid falling behind in the digital race. Both governments and private sectors play critical roles in managing digital initiatives and expanding the delivery of services to the public.

This can be achieved by investing in developing the digital infrastructure needed to enable wider access, regulatory reform, and wholesale open access to ensure competitive prices and a safe digital environment, providing public access to financially disadvantaged communities. Further, cities should invest in human capital, digital literacy, and skills, which is crucial to empower individuals to use ICT effectively to contribute to and benefit from smart city applications and raise awareness to engage the community in digital technologies.

Cities like Milan, Tallinn and Bratislava are recommended to implement strategies to improve community participation and engagement to improve their innovation and participation scores. At the same time, these cities should accelerate their investment in R&D and collaboration between companies, universities, and research centres, which would benefit their innovative capacity. By the same token, cities should encourage knowledge-intensive industries and create an enabling environment to stimulate business innovation and the quality of a city's business networks and supporting industries.

Finally, for cities like Melbourne, Montreal, and Sydney to improve their environmental community scores, it is advised that the governments encourage cities to adopt smart energy and environmental initiatives, commit to improving net-zero emissions and green renewable energy targets through green innovation, incentivise green R&D and promote green public procurement. Cities should also encourage

creativity in communities by providing free access to cultural activities and training, as well as promoting living labs.

### 5.3. How Can Systemic Governance Of Smart Cities Promote Urban Sustainability?

Awareness of the benefits smart cities can provide is growing worldwide, and cities around the globe are actively developing strategies with the aim of becoming 'smart' and managing urban resources more efficiently while facing the challenges of development and inclusion. Studying the relationship between smart city drivers and urban sustainability is vital for policymakers and smart city participants to better plan, develop and monitor the design of smart cities that can improve the quality of life and contribute to the socio-economic development of the city. Businesses and corporations have also taken various measures to achieve sustainability. For their investment decisions, it is important to understand how investments in digital infrastructure can solve urban challenges and improve the built environment.

The complexity of smart city development has led policymakers to seek short-term gains through black-box technological solutions (Yigitcanlar et al., 2019). However, our findings suggest that cities need to transform their governance, civic engagement and inter-organisational coordination and bring them into an integrated vision for a sustainable future. In particular, the findings seem to indicate that the existing governance system is unable to adequately address environmental and social sustainability. This unpleasant reality underlines the need to redesign the current policy approach and the management of the smart-sustainability nexus.

Against this backdrop, the study provides several policy suggestions that can aid policymakers in designing more integrated and proactive policies to harness the potential of smart city solutions for sustainability. First, a systemic mode of governance can serve as a policy guide so that smart cities can play an active role in an orderly fashion to achieve sustainability, as the fragmented driver-specific policy approach may fall short of driving urban sustainability. Specifically, there is a need for better coordination between smart city-led policies, with governments simultaneously guiding ICT implementation in collaboration with industry and various stakeholders. Governments should support incubators and accelerators and develop strategies to maintain cybersecurity and privacy and manage the uncertainties associated with the development of smart cities.

Second, there is a need to accumulate learning and innovation by strengthening investment in education and public services and promoting an enabling environment for business and talent. Third, governments should enforce environmental laws and regulations to avoid the rebound effect of technologies and provide incentives for citizens to behave more sustainably. Fourth, governments should fully embrace smart governance, promote collaboration among various stakeholders, involve citizens in decision-making through e-participation, strive for digital inclusivity, eliminate the demands of elites by reinforcing ethical and moral values and avoid excessive government intervention.

# CONCLUSION

Today's cities have become an engine of economic growth and a centre of talent acquisition. At the same time, cities face persistent challenges arising from ageing infrastructure, the great wave of urbanisation, the need for energy efficiency, growing global competition, and limited financial resources combined with socio-economic issues, such as inequality and unemployment. Smart cities have therefore emerged as a response to these challenges and to create new opportunities.

Firstly, modern debates continue to ask what role smart cities should play in urban planning to better address today's challenges and the accompanying growth of cities. Scholars from various disciplines, urban planners, and professionals have developed a wide array of approaches to conceptualise and track the performance of smart cities. However, the existing studies do not consider the protentional synergies and trade-offs between the indicators, nor do they examine and quantify these interlinkages. Therefore, this study provides a holistic framework for examining the interrelationships among the indicators of smart city drivers and outcomes, including the potential negative externalities of its implementation. Moreover, it identifies the most influential drivers using network analysis and proposes an updated smart city framework based on the results of network community detection.

From a broader perspective, the findings show that the key drivers for a smart city are technology and governance, as they provide the necessary framework and infrastructure for the implementation of smart solutions, followed by community, as citizens play an important role in providing feedback on the performance of city services and identifying areas for improvement, and innovative economy, which drives sustainable economic growth, and finally physical infrastructure. Implementing these drivers has a significant impact on various outcomes, including government transparency, public health, safety, and labour flexibility. However, it can also lead to potential negative externalities, including increased inequality, a digital divide, and reduced freedoms. Further, there are only a few trade-offs in the network of smart city indicators compared to the existing synergies. More specifically, information about the reinforcing and conflicting relationships among indicators helps promote such synergies and effectively mitigate the trade-offs. It can also reveal any existing consistency within a smart city framework. In addition, network statistics show that innovation, business sophistication, ICT infrastructure, and government effectiveness are the most important indicators within a smart city framework, where policymakers

can achieve greater impact by aligning their policies accordingly. Moreover, this study proposed a smart city framework based on three integrated dimensions, namely digitalisation, innovation and sustainable infrastructure, and human and social capital.

Secondly, in recent years, the number of established instruments for evaluating the performance of smart cities has increased significantly. These tools can help policymakers and smart city practitioners who often face obstacles in devising adequate smart city planning and development strategies due to the lack of comprehensive quantification of smart city indicators and impacts.

This research proposes an assessment model for smart city drivers in cities. Towards this end, the smart city drivers were identified through an extensive literature review and classified into five themes. Then, a dynamic factor analysis was performed using panel data to compare smartness between cities and highlight the changes in smartness in different cities from 2005-2019. In essence, understanding each city's different smart city development strategies is key to successful smart city implementation. The research concludes with suggestions to steer the efforts of policymakers, and private and public sectors towards more effective and efficient implementation of smart city initiatives.

Quantitative measurement and assessment of urban smartness provide an empirical basis for identifying specific city strengths and weaknesses and knowledge-based decision-making for policymakers and metropolitan leaders in selecting policies that can enhance smart city growth and performance. On the one hand, cities with weak smart city scores but high static scores in a single factor, such as Bratislava, Warsaw, Oslo, and Tallinn, should focus on their comparative advantages, enhance their competitive strength, and build socio-technical complementarities to improve their general smartness. On the other hand, cities with both weak smart city scores and static scores, such as Madrid, should take advantage of the experiences of other cities, identify their specific bottlenecks and initiate learning processes for an appropriate implementation of smart city drivers that will potentially sharpen their profile and improve their performance.

Thirdly, smart city applications foreground technology to create unsurpassed solutions to the complex societal, economic, and environmental challenges facing contemporary cities (Yigitcanlar, 2016). However, despite the popularity of the smart city paradigm, it has been criticised for being a buzzword that lacks an integrated approach to addressing sustainability concerns. More importantly, there is a lack of

empirical studies that investigate the smart city's ability to create a sustainable urban environment. Thus, empirical investigation of the sustainability outcomes of smart cities is crucial to prove whether smart city agendas contribute to sustainability.

Towards this end, a PVAR model was employed to explore the dynamic relationships between smart city drivers and dimensions of urban sustainability using panel data from 26 smart cities over the period 2009-2019. In so doing, the research develops the concepts of 'systemic governance', 'fragmented mode of smart governance', 'positive smart complementarities' and 'negative smart complementarities' to explore the bilateral effects between smartness and sustainability and whether they are incorporated in a structured or fragmented manner.

The findings suggest that the governance of smart cities is fragmented and has failed to coordinate smart and negative complementarities to achieve environmental and social sustainability. On the contrary, there is a systemic mode of governance of smart complementarities between drivers of smart cities and economic sustainability, confirming the claim that smart city development is driven by primary economic growth objectives rather than environmental and socio-economic concerns (Bibri, 2018; Haarstad, 2017).

I argue that governments should establish and maintain positive (smart) complementarity between smart city drivers and urban sustainability by aligning smart, economic, environmental, and social policy choices. These include, inter alia, increasing collaboration between government and technology companies, introducing digitalisation in urban services and governance, formulating social and environmental policies to mitigate the potential negative impacts of smart city implementation, creating a social atmosphere that encourages changes in habits and behaviours, investing in human capital, promoting citizen participation, and creating an enabling environment for business and entrepreneurship.

From a broad perspective, this research demonstrates that a smart city is a multidimensional concept that should be approached in a transdisciplinary manner. The primary objective of the study is to synthesise and systematically integrate smart city drivers to promote urban sustainability. Thus, its primary contribution is the creation of a decision-support framework that identifies the tools that policymakers, urban planners and businesses could/should use to create policies and initiatives that transition cities into smarter and more sustainable areas.

In specific, the added value of this study is manifold. First, the research provides a seminal holistic framework for examining the interrelationships among the indicators of the smart city, i.e., drivers and outcomes, including the potential negative externalities of its implementation. Identifying such central dimensions in a smart city network is anticipated to inform policymakers on prioritising smart city policies and strategies.

Second, to the best of my knowledge, the study is the first empirical investigation of the impact of smartness on urban sustainability, covering environmental, economic, and social pillars. Third, the study develops the concept of smart complementarity and introduces the concepts of systemic governance and fragmentation of complementarities suggested by Akan et al. (2021, 2018, 2022a, 2022b) for the first time in smart city research. Finally, the novelties of this study lie in the use of quantitative techniques. These include using network analysis and applying dynamic factor analysis in the context of smart cities to provide a dynamic ranking over several years.

The results of this study should be viewed in light of several limitations. First, the main challenge of the study is the availability of city-level data. Therefore, the generalisation that emerges from the study must be limited to the context of the selected cities. Second, the fact that the smart city is a new concept that is still evolving means that there may be limited data available for analysis, making choosing a reliable methodology for dynamic analysis challenging. Third, it may be daunting to explore and identify the interlinkages among smart city indicators, given that the previous studies exclusively focus on identifying smart city indicators.

Finally, smart city research is a growing field that presents enormous research opportunities due to its multidisciplinary nature. This study provides a foundation upon which future research can draw upon when conducting research of a similar nature. In this regard, future research may include additional smart city drivers/indicators, expand the research scope to include additional cities, and perform in-depth analyses of the urban smartness of cities by region.

Future studies could explore other factors that might influence urban sustainability or include other urban sustainability measures. They could also use data over a longer period and a larger sample to examine this relationship. Another avenue of research may include the application of the study frameworks at the city level, where synergies and trade-offs between various smart city indicators may vary

depending on the context of each city. Lastly, countries should report disaggregated city-level data so that the specific phenomena can be studied and addressed in a comprehensive and reliable manner.

# REFERENCES


ABHIJEET, K., 2016 — Development of National Space Law for India. **Astropolitics**, 14(2-3), 185-202.

ABRIGO, M. R., & LOVE, I., 2016 — Estimation of panel vector autoregression in Stata. **The Stata Journal**, 16(3), 778-804.

ACEMOGLU, D., 1996 — A Microfoundation for Social Increasing Returns in Human Capital Accumulation. **The Quarterly Journal of Economics**, 111(3), 779-804. https://doi.org/10.2307/2946672

ACEMOGLU, D., 1997 — Training and Innovation in an Imperfect Labour Market. **The Review of Economic Studies**, 64(3), 445. https://doi.org/10.2307/2971723

ACEMOGLU, D., ROBINSON, J. A., & WOREN, D., 2012 — **Why nations fail: The origins of power, prosperity and poverty** (Vol. 4). Crown Publishers New York.

ACS, Z. J., & SANDERS, M., 2011 — Patents, knowledge spillovers, and entrepreneurship. **Small Business Economics**, 39(4), 801-817. https://doi.org/10.1007/s11187-011-9322-y

ADEOLA, O., & EVANS, O., 2019 — Digital tourism: mobile phones, internet and tourism in Africa. **Tourism Recreation Research**, 44(2), 190-202. https://doi.org/10.1080/02508281.2018.1562662

AGHION, P., AKCIGIT, U., BERGEAUD, A., BLUNDELL, R., & HÉMOUS, D., 2019 — Innovation and top income inequality. **The Review of Economic Studies**, 86(1), 1-45.

AGHION, P., & HOWITT, P., 1990 — **A Model of Growth Through Creative Destruction**. http://dx.doi.org/10.3386/w3223

AGHION, P., HOWITT, P., HOWITT, P. W., BRANT-COLLETT, M., & GARCÍA-PEÑALOSA, C., 1998 — **Endogenous growth theory**. MIT press.

AHORTOR, C. R., & ADENUTSI, D. E., 2009 — Inflation, capital accumulation and economic growth in import-dependent developing economies. In 14th Annual Conference on Econometric modeling, Abuja, October (Vol. 20, pp. 22-40).

AHVENNIEMI, H., HUOVILA, A., PINTO-SEPPÄ, I., & AIRAKSINEN, M., 2017 — What are the differences between sustainable and smart cities? **Cities**, 60, 234-245.

AKAMA, J. S., 2002 The role of Government in the development of tourism in Kenya. **International Journal of Tourism Research**, 4(1), 1-14. https://doi.org/10.1002/jtr.318

AKAN, T., 2018 **Systemic Governance and the Fragmentation of Institutional Complementarities**. In The Complementary Roots of Growth and Development (pp. 1-16). Springer.

AKAN, T., 2022 Investigating renewable energy–climate change nexus by aggregate or sectoral renewable energy use? **Environmental Science and Pollution Research**, 1-19.

AKAN, T., GÜNDÜZ, H. İ., VANLI, T., ZEREN, A. B., IŞIK, A. H., & MASHADIHASANLI, T., 2022 Why are some countries cleaner than others? New evidence from macroeconomic governance. **Environment, Development and Sustainability**, 1-57.

AKAN, T., HEPSAG, A., BOZOKLU, S., & MOLLAAHMETOĞLU, E., 2021 Finance as a friend, enemy and stranger in the US Economy, 1952–2019. **Socio-Economic Review.**

AKAN, T., & SOLLE, T., 2022 Do macroeconomic and financial governance matter? Evidence from Germany, 1950–2019. **Journal of Economic Interaction and Coordination**, 1-53.

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.

AKER, J. C., & MBITI, I. M., 2010 Mobile phones and economic development in Africa. **Journal of Economic Perspectives**, 24(3), 207-232.

AKMAN, I., YAZICI, A., MISHRA, A., & ARIFOGLU, A., 2005 E-Government: A global view and an empirical evaluation of some attributes of citizens. **Government information quarterly**, 22(2), 239-257.

AL MAMUN, M., SOHAG, K., SHAHBAZ, M., & HAMMOUDEH, S., 2018 Financial markets, innovations and cleaner energy production in OECD countries. **Energy Economics**, 72, 236-254.

ALADWANI, A. M., 2016 Corruption as a source of e-Government projects failure in developing countries: A theoretical exposition. **International Journal of Information Management,** 36(1), 105-112.

ALAM, A., UDDIN, M., & YAZDIFAR, H., 2019 Institutional determinants of R&D investment: Evidence from emerging markets. **Technological Forecasting and Social Change**, 138, 34-44.

ALAM, M. S., & KABIR, N., 2013 Economic growth and environmental sustainability: empirical evidence from East and South-East Asia. **International Journal of Economics and Finance**, 5(2).

| | |
|---|---|
| ALA-MUTKA, K., PUNIE, Y., & REDECKER, C., 2008 | Digital competence for lifelong learning. Institute for Prospective Technological Studies (IPTS), European Commission, **Joint Research Centre**. Technical Note: JRC, 48708, 271-282. |
| ALBALATE, D., & FAGEDA, X., 2019 | Congestion, road safety, and the effectiveness of public policies in urban areas. **Sustainability**, 11(18), 5092. |
| ALBINO, V., BERARDI, U., & DANGELICO, R. M., 2015 | Smart cities: Definitions, dimensions, performance, and initiatives. **Journal of urban technology**, 22(1), 3-21. |
| ALEGRE, J., & CLADERA, M., 2006 | Repeat visitation in mature sun and sand holiday destinations. **Journal of travel Research**, 44(3), 288-297. |
| ALFARO CORTÉS, E., & ALFARO NAVARRO, J.-L., 2011 | Do ICT influence economic growth and human development in European Union countries? **International Advances in Economic Research**, 17(1), 28-44. |
| AL-HADER, M., & RODZI, A., 2009 | The smart city infrastructure development & monitoring. **Theoretical and Empirical Researches in Urban Management**, 4(2 (11), 87-94. |
| ALIZADEH, T., 2017 | An investigation of IBM's Smarter Cites Challenge: What do participating cities want? **Cities**, 63, 70-80. |
| AL-KIBSI, G., DE BOER, K., MOURSHED, M., & REA, N. P., 2001 | Putting citizens on-line, not in line. **The McKinsey Quarterly**, 64. |
| ALLAM, Z., & NEWMAN, P., 2018 | Redefining the smart city: Culture, metabolism and governance. **Smart Cities**, 1(1), 4-25. |
| ALLEN, C., METTERNICHT, G., & WIEDMANN, T., 2018 | Initial progress in implementing the Sustainable Development Goals (SDGs): A review of evidence from countries. **Sustainability Science**, 13(5), 1453-1467. |
| ALSHAHADEH, T., & MARSAP, A., 2018 | Smart Cities, Smarter Management: Developing A SMART Framework For Smart City Projects Management In Europe. **GE-International Journal of Managemen**t, 6(9). |
| ALSTON, P., 2020 | The parlous state of poverty eradication: Report of the Special Rapporteur on extreme poverty and human rights. **Human Rights Council**. |
| ALTINDAG, D. T., 2014 | Crime and international tourism. **Journal of Labor Research**, 35(1), 1-14. |
| AMBROSETTI, E., & PAPARUSSO, A., 2020 | Subjective Well-Being of Immigrants in Italy. **In Encyclopedia of Quality of Life and Well-Being Research** (pp. 1-8): Springer International Publishing. |
| AMBROSETTI, F., 2012 | Smart Cities in Italy: an opportunity in the spirit of the renaissance for a new quality of life. **ABB-The European House Ambrosetti.** |

ANAND, A., WINFRED RUFUSS, D. D., RAJKUMAR, V., & SUGANTHI, L., 2017 Evaluation of Sustainability Indicators in Smart Cities for India Using MCDM Approach. **Energy Procedia**, 141, 211-215. https://doi.org/10.1016/j.egypro.2017.11.094

ANDERSEN, T. B., 2009 E-Government as an anti-corruption strategy. **Information Economics and policy**, 21(3), 201-210.

ANDERSON, A., 2012 Climate change education for mitigation and adaptation. **Journal of Education for Sustainable Development**, 6(2), 191-206.

ANDRIANAIVO, M., & KPODAR, K. R., 2011 ICT, financial inclusion, and growth: Evidence from African countries. **IMF Working Papers**, 2011(073).

ANDUIZA, E., GALLEGO, A., & CANTIJOCH, M., 2010 Online political participation in Spain: the impact of traditional and Internet resources. **Journal of Information Technology & Politics**, 7(4), 356-368.

ANGELIDOU, M., 2014 Smart city policies: A spatial approach. **Cities**, 41, S3-S11.

ANGELOPOULOS, K., ECONOMIDES, G., & PHILIPPOPOULOS, A., 2010 **What is the best environmental policy?** Taxes, permits and rules under economic and environmental uncertainty.

ANGOSO, J., 2009 The ICT infrastructure for ecoefficient cities. **High level OECD conference.**

ANHEIER, H. K., 2004 Global civil society 2004/5. **Sage**.

ANOKHIN, S., & SCHULZE, W. S., 2009 Entrepreneurship, innovation, and corruption. **Journal of business venturing**, 24(5), 465-476.

ANTHOPOULOS, L., 2017 Smart utopia VS smart reality: Learning by experience from 10 smart city cases. **Cities**, 63, 128-148.

ANTONAKAKIS, N., CHATZIANTONIOU, I., & FILIS, G., 2017 Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. **Renewable and Sustainable Energy Reviews**, 68, 808-824.

ANTROBUS, D., 2011 Smart green cities: from modernization to resilience? **Urban Research & Practice**, 4(2), 207-214.

ANTTIROIKO, A.-V., 2013 U-cities reshaping our future: reflections on ubiquitous infrastructure as an enabler of smart urban development. **AI & society**, 28(4), 491-507.

APARICIO, S., URBANO, D., & AUDRETSCH, D., 2016 Institutional factors, opportunity entrepreneurship and economic growth: Panel data evidence. **Technological Forecasting and Social Change**, 102, 45-61.

APPIO, F. P., LIMA, M., & PAROUTIS, S., 2019 Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges. **Technological Forecasting and Social Change**, 142, 1-14.

ARAYANKALAM, J., KHAN, A., & KRISHNAN, S., 2021 How to deal with corruption? Examining the roles of e-government maturity, government administrative effectiveness, and virtual social networks diffusion.

**International Journal of Information Management**, 58, 102203.

ARKO-COBBAH, A., 2006 — Civil society and good governance: challenges for public libraries in South Africa. **Library review**.

ARORA, A., BELENZON, S., PATACCONI, A., & SUH, J., 2020 — The changing structure of American innovation: Some cautionary remarks for economic growth. **Innovation Policy and the Economy**, 20(1), 39-93.

ARROW, K., DASGUPTA, P., GOULDER, L., DAILY, G., EHRLICH, P., HEAL, G., LEVIN, S., MÄLER, K.-G., SCHNEIDER, S., & STARRETT, D., 2004 — Are we consuming too much? **Journal of Economic Perspectives**, 18(3), 147-172.

ASHFORD, N. A., 2002 — Government and environmental innovation in Europe and North America. **American Behavioral Scientist**, 45(9), 1417-1434.

ÅSTRÖM, C., ROCKLÖV, J., HALES, S., BÉGUIN, A., LOUIS, V., & SAUERBORN, R., 2012 — Potential distribution of dengue fever under scenarios of climate change and economic development. **Ecohealth**, 9(4), 448-454.

ATEMS, B., & SHAND, G., 2018 — An empirical analysis of the relationship between entrepreneurship and income inequality. **Small Business Economics**, 51(4), 905-922.

ATKINSON, A., 2007 — Cities after oil—1:'Sustainable development and energy futures. **City**, 11(2), 201-213.

ATKINSON, R. D., CASTRO, D., & EZELL, S. J., 2009 — The Digital Road to Recovery: A Stimulus Plan to Create Jobs. Boost Productivity and Revitalize America, **The Information Technology and Innovation Foundation, Washington, DC.**

ATTEWELL, P., 2001 — Comment: The first and second digital divides. **Sociology of education**, 74(3), 252-259.

AUDIA, P. G., & GONCALO, J. A., 2007 — Past success and creativity over time: A study of inventors in the hard disk drive industry. Management science, 53(1), 1-15.

AUDRETSCH, D. B., 1995 — Innovation, growth and survival. **International journal of industrial organization**, 13(4), 441-457.

AUDRETSCH, D. B., CUNNINGHAM, J. A., KURATKO, D. F., LEHMANN, E. E., & MENTER, M., 2019 — Entrepreneurial ecosystems: economic, technological, and societal impacts. **The Journal of technology transfer**, 44(2), 313-325.

AUDRETSCH, D. B., KEILBACH, M. C., & LEHMANN, E. E., 2006 **Entrepreneurship and economic growth**. Oxford University Press.

AUGUSTE, D., 2020 Who becomes a business owner in high-inequality regimes? The conditioning effect of economic inequality on the impact of individual educational and financial endowment on entrepreneurship. **Social Currents**, 7(2), 131-154.

AYRES, R. U., 1978 Resources, environment, and economics: Applications of the materials/energy balance principle.

AYRES, R. U., 2008 Sustainability economics: Where do we stand? **Ecological economics**, 67(2), 281-310.

AYRES, R. U., & KNEESE, A. V., 1969 Production, consumption, and externalities. **The American Economic Review**, 59(3), 282-297.

BAER, J., & KAUFMAN, J. C., 2006 **Creativity Research in English-Speaking Countries**. Cambridge University Press.

BAFFOE, G., & MUTISYA, E., 2015 Social sustainability: A review of indicators and empirical application. Environmental Management and Sustainable Development, 4(2), 242-262.

BAI, X., BRONDIZIO, E. S., BULLARD, R. D., EDWARDS, G. A., GRIMM, N. B., LORA-WAINWRIGHT, A., ÖZKAYNAK, B., & SCHINDLER, S., 2018 Urban environments and environmentalisms. **Rethinking Environmentalism: Linking Justice, Sustainability, and Diversity**, 23, 127-150.

BAILEY, M. J., 1956 The welfare cost of inflationary finance. **Journal of political Economy**, 64(2), 93-110.

BAKICI, T., ALMIRALL, E., & WAREHAM, J., 2013 A smart city initiative: the case of Barcelona. **Journal of the knowledge economy**, 4(2), 135-148.

BALAKRISHNA, C., 2012 **Enabling technologies for smart city services and applications**. 2012 sixth international conference on next generation mobile applications, services and technologies.

BALLAS, D., 2013 What makes a 'happy city'? **Cities**, 32, S39-S50.

BAÑON GOMIS, A. J., GUILLÉN PARRA, M., HOFFMAN, W. M., & MCNULTY, R. E., 2011 Rethinking the concept of sustainability. **Business and Society Review**, 116(2), 171-191.

BARABÁSI, A.-L., 2003 **Linked: The new science of networks.** In: American Association of Physics Teachers.

BARRAKET, D. J., 2005 Putting people in the picture? The role of the arts in social inclusion.

BARRIONUEVO, J. M., BERRONE, P., & RICART, J. E., 2012 Smart cities, sustainable progress. **IESE Insight**, 14(14), 50-57.

BARSI, B., 2018 Beyond indicators, new methods in Smart city assessment. **Orașe Inteligente Și Dezvoltare Regională**, 2(01), 87-100.

BASIAGO, A. D., 1998 Economic, social, and environmental sustainability in development theory and urban planning practice. **Environmentalist**, 19(2), 145-161.

BASIRI, M., AZIM, A. Z., & FARROKHI, M., 2017 Smart city solution for sustainable urban development. **European Journal of Sustainable Development**, 6(1), 71-71.

BATTY, M., 2012 Building a science of cities. Cities, 29, S9-S16.

BAUCELLS, N., MORENO, C., & ARCE, R. M., 2016 **Mapping smart cities situation+ cities: the Spanish case.** International Conference On Smart Cities.

BAUER, D. C., 1979 **Economic development and the older worker: A technical assistance guide for economic development district**s. National Council on the Aging.

BAUGHN, C. C., CHUA, B. L., & NEUPERT, K. E., 2006 The normative context for women's participation in entrepreneruship: A multicountry study. **Entrepreneurship theory and practice**, 30(5), 687-708.

BAUMOL, W. J., PANZAR, JOHN C., WILLIG, ROBERT D., 1988 **Contestable Markets and the Theory of Industry Structure**. Harcourt Brace Jovanovich.

BAUMOL, W. J., 1990 Quality changes and productivity measurement: Hedonics and an alternative. **Journal of Accounting, Auditing & Financ**e, 5(1), 105-117.

BAUMOL, W. J., 2007 On income distribution and growth. **Journal of Policy Modeling**, 29(4), 545-548.

BAYKURT, B., & RAETZSCH, C., 2020 What smartness does in the smart city: From visions to policy. **Convergence**, 26(4), 775-789.

BAYRAKTAR, N., 2015 Importance of investment climates for inflows of foreign direct investment in developing countries. Business and Economic Research, 5(1), 24-50.

BEATLEY, T., & WHEELER, S. M., 2004 **The sustainable urban development reader**. Routledge.

BEER, T., CURTIS, D., & COLLINS, J., 2018 Innovation: Creativity as a Renewable Resource for the Eco-City. **In Enabling Eco-Cities** (pp. 21-41). Springer.

BELAL, A., & SHCHERBINA, E., 2018 **Smart-Technology In City Planning Of Post-War Cities**. IOP conference series: materials science and engineering.

| | |
|---|---|
| BÉLISSENT, J., 2010 | **Getting clever about smart cities: New opportunities require new business models.** Cambridge, Massachusetts, USA, 193, 244-277. |
| BELL, M. L., DAVIS, D. L., & FLETCHER, T., 2004 | A retrospective assessment of mortality from the London smog episode of 1952: the role of influenza and pollution. **Environmental health perspectives**, 112(1), 6-8. |
| BEN-ELI, M. U., 2018 | Sustainability: definition and five core principles, a systems perspective. **Sustainability Science**, 13(5), 1337-1343. |
| BERACHA, E., & HARDIN III, W. G., 2021 | The housing price premium associated with charter schools. **Real Estate Economics**, 49(4), 1267-1289. |
| BERARDI, U., 2013 | Sustainability assessment of urban communities through rating systems. **Environment, Development and Sustainability**, 15(6), 1573-1591. |
| BERNARDO, M. D. R. M., 2019 | Smart city governance: from e-government to smart governance. **In Smart Cities and Smart Spaces: Concepts, Methodologies, Tools, and Applications** (pp. 196-232). IGI Global. |
| BERNAUER, T., GAMPFER, R., MENG, T., & SU, Y.-S., 2016 | Could more civil society involvement increase public support for climate policy-making? Evidence from a survey experiment in China. **Global Environmental Change**, 40, 1-12. |
| BERR, E., 2009 | Keynes and sustainable development. International Journal of Political Economy, 38(3), 22-38. |
| BERR, E., 2015 | Sustainable development in a post Keynesian perspective: why eco-development is relevant to post Keynesian economics. **Journal of Post Keynesian Economics**, 37(3), 459-480. |
| BERRONE, P., & RICART, J., 2020 | **IESE Cities in Motion Index 2020**. IESE Business School University of Navarra: Barcelona, Spain. |
| BERRONE, P., RICART, J., CARRASO, C., & RICART, R., 2016 | **IESE cities in motion index**, 2016, 60. In. |
| BERRY, C. R., & GLAESER, E. L., 2005 | The divergence of human capital levels across cities. **Papers in regional science**, 84(3), 407-444. |
| BERTINI, R., ROSCIGNO, M., FRESCHI, M., STRADA, E., PETRALIA, G., PASTA, A., MATLOOB, R., SOZZI, F., DA POZZO, L., & COLOMBO, R., 2009 | Renal sinus fat invasion in pT3a clear cell renal cell carcinoma affects outcomes of patients without nodal involvement or distant metastases. **The Journal of urology**, 181(5), 2027-2032. |

| | |
|---|---|
| BERTOT, J. C., JAEGER, P. T., & GRIMES, J. M., 2010 | Using ICTs to create a culture of transparency: E-government and social media as openness and anti-corruption tools for societies. **Government information quarterly**, 27(3), 264-271. |
| BESLEY, T., 2015 | Law, regulation, and the business climate: The nature and influence of the World Bank Doing Business project. **Journal of Economic Perspectives**, 29(3), 99-120. |
| BETTENCOURT, L., & WEST, G., 2010 | A unified theory of urban living. **Nature**, 467(7318), 912-913. |
| BHATNAGAR, S., 2003 | Transparency and corruption: Does e-government help. **DRAFT Paper prepared for the compilation of CHRI**, 1-9. |
| BIAGI, B., BRANDANO, M. G., & LAMBIRI, D., 2015 | Does Tourism Affect House Prices? Evidence from Italy. **Growth and Change**, 46(3), 501-528. |
| BIBRI, S. E., 2018 | A foundational framework for smart sustainable city development: Theoretical, disciplinary, and discursive dimensions and their synergies. **Sustainable cities and society**, 38, 758-794. |
| BIBRI, S. E., & KROGSTIE, J., 2017 | Smart sustainable cities of the future: An extensive interdisciplinary literature review. **Sustainable cities and society**, 31, 183-212. |
| BIFULCO, F., TREGUA, M., AMITRANO, C. C., & D'AURIA, A., 2016 | ICT and sustainability in smart cities management. **International Journal of Public Sector Management.** |
| BILANDZIC, M., & FOTH, M., 2013 | Libraries as coworking spaces: Understanding user motivations and perceived barriers to social learning. **Library Hi Tech.** |
| BILLINGS, S. B., DEMING, D. J., & ROCKOFF, J., 2014 | School segregation, educational attainment, and crime: Evidence from the end of busing in Charlotte-Mecklenburg. **The Quarterly Journal of Economics**, 129(1), 435-476. |
| BILLON, M., MARCO, R., & LERA-LOPEZ, F., 2017 | Innovation and ICT use in the EU: An analysis of regional drivers. **Empirical Economics**, 53(3), 1083-1108. |
| BJØRNSKOV, C., & FOSS, N., 2013 | How strategic entrepreneurship and the institutional context drive economic growth. **Strategic Entrepreneurship Journal**, 7(1), 50-69. |
| BLONDEL, V. D., GUILLAUME, J.-L., LAMBIOTTE, R., & LEFEBVRE, E., 2008 | Fast unfolding of communities in large networks. **Journal of statistical mechanics: theory and experiment**, 2008(10), P10008. |
| BLOOM, D. E., & CANNING, D., 2000 | The health and wealth of nations. **Science**, 287(5456), 1207-1209. |

BODENHEIMER, S., 1970 — Dependency and imperialism: The roots of Latin American underdevelopment. **Nacla Newsletter**, 4(3), 18-27.

BODMAN, P., & LE, T., 2013 — Assessing the roles that absorptive capacity and economic distance play in the foreign direct investment-productivity growth nexus. **Applied Economics**, 45(8), 1027-1039.

BOLÍVAR, M. P. R., & MEIJER, A. J., 2016 — Smart governance: Using a literature review and empirical analysis to build a research model. **Social science computer review**, 34(6), 673-692.

BOLLIER, D., 1998 — **How Smart Growth Can Stop Sprawl: A Fledgling Citizen Movement Expands: A Briefing Guide for Funders**. Essential Books.

BONFADELLI, H., 2002 — The Internet and knowledge gaps: A theoretical and empirical investigation. **European Journal of communication**, 17(1), 65-84.

BORGATTI, S. P., 2005 — Centrality and network flow. **Social networks**, 27(1), 55-71.

BORGHESI, S., 2006 — Income inequality and the environmental Kuznets curve. **Environment, inequality and collective action**, 33.

BORSEKOVA, K., KORÓNY, S., VAŇOVÁ, A., & VITÁLIŠOVÁ, K., 2018 — Functionality between the size and indicators of smart cities: A research challenge with policy implications. **Cities**, 78, 17-26.

BOSCH, P., JONGENEEL, S., ROVERS, V., NEUMANN, H.-M., AIRAKSINEN, M., & HUOVILA, A., 2017 — **CITYkeys indicators for smart city projects and smart cities**. CITYkeys report.

BOSSEL, H., 1999 — Indicators for sustainable development: theory, method, applications.

BOSTRÖM, M., 2012 — A missing pillar? Challenges in theorizing and practicing social sustainability: introduction to the special issue. **Sustainability: Science, practice and policy**, 8(1), 3-14.

BOULDING, K. E., 1966 — **The economics of the coming spaceship earth**. New York, 1-17.

BOULIANNE, S., 2009 — Does Internet use affect engagement? A meta-analysis of research. **Political Communication**, 26(2), 193-211.

BOULTON, A., BRUNN, S. D., & DEVRIENDT, L., 2011 — Cyberinfrastructures and 'smart'world cities: physical, human and soft infrastructures. **In International handbook of globalization and world cities**. Edward Elgar Publishing.

| | |
|---|---|
| BOVENS, M., & WILLE, A., 2010 | The education gap in participation and its political consequences. **Acta Politica**, 45(4), 393-422. |
| BOYCE, J. K., 1994 | Inequality as a cause of environmental degradation. **Ecological economic**s, 11(3), 169-178. |
| BOYER, R., 2005 | Coherence, diversity, and the evolution of capitalisms—the institutional complementarity hypothesis. **Evolutionary and Institutional Economics Review**, 2(1), 43-80. |
| BOYER, R., 2006 | How do institutions cohere and change. **Institutions and working life**, 13-61. |
| BRAAT, L. C., & VAN LIEROP, W. F., 1987 | **Economic-ecological modeling.** North Holland Publishing Co. |
| BRADLEY, P., 2021 | An institutional economics framework to explore sustainable production and consumption. **Sustainable Production and Consumption**, 27, 1317-1339. |
| BRAMLEY, G., DEMPSEY, N., POWER, S., BROWN, C., & WATKINS, D., 2009 | Social sustainability and urban form: evidence from five British cities. **Environment and Planning**, 41(9), 2125-2142. |
| BRAND, U., 2012 | Green economy–the next oxymoron? No lessons learned from failures of implementing sustainable development. **GAIA-Ecological Perspectives for Science and Society**, 21(1), 28-32. |
| BRANDT, W., 1980 | North South: a programme for survival |
| BRANDT, W., 1983 | Common crisis North-South: cooperation for world recovery. |
| BRAUN, T., FUNG, B. C., IQBAL, F., & SHAH, B., 2018 | Security and privacy challenges in smart cities. **Sustainable cities and society**, 39, 499-507. |
| BREAU, S., KOGLER, D. F., & BOLTON, K. C., 2014 | On the Relationship between Innovation and Wage Inequality: New Evidence from Canadian Cities. **Economic Geography**, 90(4), 351-373. |
| BRESSERS, H., BRESSERS, N., KUKS, S., & LARRUE, C., 2016 | The governance assessment tool and its use. **In Governance for drought resilience** (pp. 45-65). Springer, Cham. |
| BREUER, A., JANETSCHEK, H., & MALERBA, D., 2019 | Translating sustainable development goal (SDG) interdependencies into policy advice. B, 11(7), 2092. |
| BRODHAG, C., & TALIÈRE, S., 2006 | **Sustainable development strategies: tools for policy coherence.** Natural resources forum. |
| BROOKS, A. C., 2002 | Does civil society stop the downward spiral of bad government or speed it up? **Nonprofit and Voluntary Sector Quarterly**, 31(1), 140-144. |

BRORSTRÖM, S., ARGENTO, D., GROSSI, G., THOMASSON, A., & ALMQVIST, R., 2018 Translating sustainable and smart city strategies into performance measurement systems. **Public Money & Management**, 38(3), 193-202.

BROUWER, E., KLEINKNECHT, A., & REIJNEN, J. O., 1993 Employment growth and innovation at the firm level. J**ournal of Evolutionary Economics**, 3(2), 153-159.

BROWN, B. J., HANSON, M. E., LIVERMAN, D. M., & MERIDETH, R. W., 1987 Global sustainability: Toward definition. **Environmental management**, 11(6), 713-719.

BRUNDTLAND, G. H., 1987 Report of the World Commission on environment and development: "**our common future**". UN.

BRUNDTLAND, G. H., & MANSOUR, K., 2010 World Commission on Environment and Development (WCED). 1987. **Our common future**, 2010.

BUHALIS, D., & LAW, R., 2008 Progress in information technology and tourism management: 20 years on and 10 years after the Internet—The state of eTourism research. **Tourism Management**, 29(4), 609-623.

BULUT, U., KOCAK, E., & SUESS, C., 2020 The effect of freedom on international tourism demand: Empirical evidence from the top eight most visited countries. **Tourism Economics**, 26(8), 1358-1373.

BUONANNO, P., & LEONIDA, L., 2006 Education and crime: evidence from Italian regions. **Applied Economics Letters**, 13(11), 709-713.

BUONOCORE, J. J., LUCKOW, P., NORRIS, G., SPENGLER, J. D., BIEWALD, B., FISHER, J., & LEVY, J. I., 2016 Health and climate benefits of different energy-efficiency and renewable energy choices. **Nature Climate Change**, 6(1), 100-105.

CABARINO, J., 1992 **Towards a Sustainable Society**. Chicago: Noble.

CADORET, I., & PADOVANO, F., 2016 The political drivers of renewable energies policies. **Energy Economics**, 56, 261-269.

CAIRD, S., HUDSON, L., & KORTUEM, G., 2016 A tale of evaluation and reporting in UK smart cities.

CAIRD, S., HUDSON, L., & KORTUEM, G., 2017 **Communication on Smart City Evaluation and Reporting In UK cities: Pilots, Demos and Experiments Case**. In: Smart Cities in Smart Regions 2016: Conference Proceedings.

CALDWELL, L. K., & WEILAND, P. S., 1996 **International environmental policy: from the twentieth to the twenty-first century**. Duke University Press.

CALVILLO, C. F., SÁNCHEZ-MIRALLES, A., & VILLAR, J., 2016 Energy management and planning in smart cities. **Renewable and Sustainable Energy Reviews**, 55, 273-287.

CALVÓ-ARMENGOL, A., & ZENOU, Y., 2003 Does crime affect unemployment? The role of social networks. **Annales d'Economie et de Statistique**, 173-188.

CALZADA, I., & COBO, C., 2015 Unplugging: Deconstructing the smart city. **Journal of urban technology**, 22(1), 23-43.

CAMAGNI, R., 1998 Sustainable urban development: definition and reasons for a research programme. **International Journal of Environment and Pollution**, 10(1), 6-27.

CAMAGNI, R., & CAPELLO, R., 2013 Regional competitiveness and territorial capital: a conceptual approach and empirical evidence from the European Union. **Regional Studies**, 47(9), 1383-1402.

CAMAGNI, R., CAPELLO, R., & CARAGLIU, A., 2013 One or infinite optimal city sizes? In search of an equilibrium size for cities. **The Annals of Regional Science**, 51(2), 309-341.

CAMAGNI, R., CAPELLO, R., & NIJKAMP, P., 1998 Towards sustainable city policy: an economy-environment technology nexus. **Ecological economics**, 24(1), 103-118.

CAMBIR, A., & VASILE, V., 2015 Material dimension of life quality and social inclusion. **Procedia Economics and Finance**, 32, 932-939.

CAMPAGNOLO, L., CARRARO, C., EBOLI, F., FARNIA, L., PARRADO, R., & PIERFEDERICI, R., 2018 The ex-ante evaluation of achieving sustainable development goals. **Social Indicators Research**, 136(1), 73-116.

CAMPBELL, D. E., 2006 **Why we vote: How schools and communities shape our civic life** (Vol. 100). Princeton University Press.

CAMPOS, J. E., LIEN, D., & PRADHAN, S., 1999 The impact of corruption on investment: Predictability matters. **World Development**, 27(6), 1059-1067.

CAO, J., EMISSION., 2017 Trading contract and its regulation. **Journal of Chongqing University** (social science edition), 23, 84-90.

CARAGLIU, A., DEL BO, C., & NIJKAMP, P., 2011 Smart cities in Europe. **Journal of urban technology**, 18(2), 65-82.

CARAGLIU, A., DEL BO, C., & NIJKAMP, P., 2013 Smart cities in Europe. **Smart Cities** (pp. 185-207). Routledge.

CARAGLIU, A., & DEL BO, C. F., 2019 Smart innovative cities: The impact of Smart City policies on urban innovation. **Technological Forecasting and Social Change**, 142, 373-383.

CARAYANNIS, E. G., & FORMICA, P., 2006 Intellectual venture capitalists: an emerging breed of knowledge entrepreneurs. **Industry and Higher Education**, 20(3), 151-156.

CARDULLO, P., & KITCHIN, R., 2019 Being a 'citizen'in the smart city: Up and down the scaffold of smart citizen participation in Dublin, Ireland. **GeoJournal**, 84(1), 1-13.

CARRILLO, F. J., YIGITCANLAR, T., GARCÍA, B., & LÖNNQVIST, A., 2014 **Knowledge and the city: Concepts, applications and trends of knowledge-based urban development.** Routledge.

CARRIÓN-FLORES, C. E., & INNES, R., 2010 Environmental innovation and environmental performance. **Journal of environmental economics and management**, 59(1), 27-42.

CASTELLANO, R., & ROCCA, A., 2017 The dynamic of the gender gap in the European labour market in the years of economic crisis. **Quality & Quantity**, 51(3), 1337-1357.

CASTRO, C. J., 2004 Sustainable development: mainstream and critical perspectives. **Organization & Environment**, 17(2), 195-225.

CECCATO, V., & WILHELMSSON, M., 2020 Do crime hot spots affect housing prices? **Nordic journal of criminology**, 21(1), 84-102.

CENTRE, S., 2002 Environment and development - towards a common strategy of the south in the UNCED negotiations and beyond." the south and sustainable development conundrum: from Stockholm 1972 to Rio 1992 to Johannesburg 2002.

CERISOLA, S., 2019 **Cultural heritage, creativity and economic development**. Edward Elgar Publishing.

CHAKRABORTY, I., GOLDSTEIN, I., & MACKINLAY, A., 2018 Housing price booms and crowding-out effects in bank lending. **The Review of Financial Studies**, 31(7), 2806-2853.

CHANG, T., GRAFF ZIVIN, J., GROSS, T., & NEIDELL, M., 2016 Particulate pollution and the productivity of pear packers. American Economic Journal: **Economic Policy**, 8(3), 141-169.

CHANG, Y., WONG, S. F., LIBAQUE-SAENZ, C. F., & LEE, H., 2018 The role of privacy policy on consumers' perceived privacy. **Government information quarterly**, 35(3), 445-459.

CHAVAN, S., & CHAVAN, M., 2020 Recent trends in ICT-enabled renewable energy systems. **In Information and Communication Technology for Sustainable Development** (pp. 327-332). Springer.

CHECCHI, D., 2001 **Education, inequality and income inequality.** LSE STICERD Research Paper (52).

CHEN, Y.-S., LAI, S.-B., & WEN, C.-T., 2006 The influence of green innovation performance on corporate advantage in Taiwan. **Journal of business ethics**, 67(4), 331-339.

CHI, W., & QIAN, X., 2010 The role of education in regional innovation activities: spatial evidence from China. **Journal of the Asia Pacific economy**, 15(4), 396-419.

CHOI, C., & YI, M. H., 2018 — The Internet, R&D expenditure and economic growth. **Applied Economics Letters**, 25(4), 264-267.

CHONG, A., & CALDERON, C., 2000 — Institutional quality and income distribution. **Economic Development and Cultural Change**, 48(4), 761-786.

CHOURABI, H., NAM, T., WALKER, S., GIL-GARCIA, J. R., MELLOULI, S., NAHON, K., PARDO, T. A., & SCHOLL, H. J., 2012 — **Understanding smart cities: an integrative framework**. 2012 45th Hawaii international conference on system sciences.

CIANGA, N., & POPESCU, C., 2013 — Green Spaces and Urban Tourism Development in Craiova Municipality In Romania. **European Journal of Geography**, 4(2), 34-45.

ČIEGIS, R., ČIEGIS, R., & JASINSKAS, E., 2005 — Concepts of strong comparability and commensurability versus concepts of strong and weak sustainability. I**nžinerinė ekonomika**(5), 31-35.

CLAIBORNE, R., 1972 — The closing circle: nature, man and technology. **Hospital Practice**, 7(2), 159-167.

CLEMONS, E. K., HANN, I.-H., & HITT, L. M., 2002 — Price dispersion and differentiation in online travel: An empirical investigation. **Management science**, 48(4), 534-549.

CLIFT, S. L., 2004 — E-government and democracy. **Representation and citizen engagement in the information age**, 40.

COASE, R., 1960 — The Journal of LAW c. **Journal of Law and Economics**, 3, 1-44.

COE, D. T., & HELPMAN, E., 1995 — International R&D spillovers. **European economic review**, 39(5), 859-887.

COHEN, G., SALOMON, I., & NIJKAMP, P., 2002 — Information–communications technologies (ICT) and transport: does knowledge underpin policy? **Telecommunications Policy**, 26(1-2), 31-52.

COLANTONIO, A., 2010 — Urban social sustainability themes and assessment methods. Proceedings of the Institution of Civil **Engineers-Urban Design and Planning**, 163(2), 79-88.

COLBY, M. E., 1991 — Environmental management in development: the evolution of paradigms. **Ecological economics**, 3(3), 193-213.

COLDING, J., & BARTHEL, S., 2017 — An urban ecology critique on the “Smart City” model. **Journal of cleaner production**, 164, 95-101.

COLDING, J., COLDING, M., & BARTHEL, S., 2020 — The smart city model: A new panacea for urban sustainability or unmanageable complexity? Environment and Planning B: **Urban Analytics and City Science**, 47(1), 179-187.

| | |
|---|---|
| COLE, H. S., 1973 | **Thinking about the Future: A Critique of the Limits to Growth.** London: Chatto & Windus for Sussex University Press. |
| COLE, M. A., ELLIOTT, R. J., & SHIMAMOTO, K., 2005 | Industrial characteristics, environmental regulations and air pollution: an analysis of the UK manufacturing sector. **Journal of environmental economics and management**, 50(1), 121-143. |
| COLE, S., 2018 | **Gender equality and tourism: Beyond empowerment**. CABI. |
| COLLADOS, C., & DUANE, T. P., 1999 | Natural capital and quality of life: a model for evaluating the sustainability of alternative regional development paths. **Ecological economics**, 30(3), 441-460. |
| COLLDAHL, C., FREY, S., & KELEMEN, J. E., 2013 | **Smart cities: Strategic sustainable development for an urban world.** Blekinge Institute of Technology, Karlskrona, Sweden |
| COLLET, C., HINE, D., & DU PLESSIS, K., 2015 | Employability skills: perspectives from a knowledge-intensive industry. **Education+ Training.** |
| COLLSTE, D., PEDERCINI, M., & CORNELL, S. E., 2017 | Policy coherence to achieve the SDGs: using integrated simulation models to assess effective policies. **Sustainability Science**, 12(6), 921-931. |
| COMBES, P.-P., DURANTON, G., & GOBILLON, L., 2008 | Spatial wage disparities: Sorting matters! **Journal of urban economics**, 63(2), 723-742. |
| CONDIT FAGAN, J., & FAGAN, B. D., 2001 | Citizens' access to on-line state legislative documents. B, 18(2), 105-121. https://doi.org/10.1016/s0740-624x(01)00064-8 |
| COPPI, R., 1986 | Analysis of three-way data matrices based on pairwise relation measures. **Compstat**. |
| COPPI, R., & ZANNELLA, F., 1978 | L'analisi fattoriale di una serie temporale multipla relativa allo stesso insieme di unità statistiche. **Atti della XXIX Riunione Scientifica della SIS**, Bologna. |
| CORDELLA, A., & IANNACCI, F., 2010 | Information systems in the public sector: The e-Government enactment framework. **The Journal of Strategic Information Systems**, 19(1), 52-66. |
| COROAMA, V. C., SCHIEN, D., PREIST, C., & HILTY, L. M., 2015 | The energy intensity of the Internet: home and access networks. **In ICT Innovations for Sustainability** (pp. 137-155). Springer. |
| CORREIA, D., TEIXEIRA, L., & MARQUES, J., 2020 | Triangular pyramid trunk: The three axes of the smart city assessment tool. **WIT Transactions on Ecology and the Environment**, 241, 79-90. |
| COSGRAVE, E., ARBUTHNOT, K., & TRYFONAS, T., 2013 | Living labs, innovation districts and information marketplaces: A systems approach for smart cities. **Procedia Computer Science**, 16, 668-677. |
| COSTANZA, R., & PATTEN, B. C., 1995 | Defining and predicting sustainability. **Ecological economics**, 15(3), 193-196. |

COWLEY, R., & CAPROTTI, F., 2019 Smart city as anti-planning in the UK. Environment and Planning D: **Society and Space**, 37(3), 428-448.

CREED, P. A., & REYNOLDS, J., 2001 Economic deprivation, experiential deprivation and social loneliness in unemployed and employed youth. J**ournal of Community & Applied Social Psychology**, 11(3), 167-178.

CREMONINI, L., & VALERI, L., 2003 **Benchmarking Security and Trust in Europe and the US.** Rand Corporation.

CRESCENZI, R., DI CATALDO, M., & RODRÍGUEZ-POSE, A., 2016 Government quality and the economic returns of transport infrastructure investment in European regions. **Journal of Regional Science**, 56(4), 555-582.

CUI, X., & RYAN, C., 2011 Perceptions of place, modernity and the impacts of tourism–Differences among rural and urban residents of Ankang, China: A likelihood ratio analysis. **Tourism Management**, 32(3), 604-615.

CULE, M., & FULTON, M., 2013 Corporate governance and subjective well-being. **Applied Economics Letters**, 20(4), 364-367.

CULLEN, R., 2001 Addressing the digital divide. **Online information review.**

CURRIE, J., & NEIDELL, M., 2005 Air pollution and infant health: what can we learn from California's recent experience? **The Quarterly Journal of Economics**, 120(3), 1003-1030.

CUSTERS, B., DECHESNE, F., SEARS, A. M., TANI, T., & VAN DER HOF, S., 2018 A comparison of data protection legislation and policies across the EU. **Computer Law & Security Review**, 34(2), 234-243.

DABLA-NORRIS, M. E., KOCHHAR, M. K., SUPHAPHIPHAT, M. N., RICKA, M. F., & TSOUNTA, M. E., 2015 **Causes and consequences of income inequality: A global perspective**. International Monetary Fund.

DAHL, R. A., 1971 **Polyarchy : participation and opposition.** Yale University Press.

DALEVSKA, N., KHOBTA, V., KWILINSKI, A., & KRAVCHENKO, S., 2019 A model for estimating social and economic indicators of sustainable development. **Entrepreneurship and sustainability issues**, 6(4), 1839.

DALLE NOGARE, C., & MURZYN-KUPISZ, M., 2021 Do museums foster innovation through engagement with the cultural and creative industries? **Journal of Cultural Economics**, 1-34.

DALY, H. E., 1991 **Steady-state economics: with new essays**. Island press.

DALY, H. E., 1991 Towards an environmental macroeconomics. **Land economics**, 67(2), 255-259.

DALY, H. E., & DALY, H. E., 1973 B (Vol. 2). WH Freeman San Francisco.

DALY, H. E., & FARLEY, J., 2011 **Ecological economics: principles and applications.** Island press.

DAMERI, R. P., 2012 **Defining an evaluation framework for digital cities implementation.** International conference on information society.

DAMERI, R. P., 2013 Searching for smart city definition: a comprehensive proposal. **International Journal of computers & technology**, 11(5), 2544-2551.

DAMIJAN, J. P., KOSTEVC, Č., & ROJEC, M., 2011 Innovation and firms' productivity growth in Slovenia: Sensitivity of results to sectoral heterogeneity and to estimation method. **In Innovation, Growth and Competitiveness** (pp. 165-193). Springer.

DANGSCHAT, J., 2001 Hamburg vor Köln und München, Berlin deutlich dahinter, Leipzig abgeschlagen. Warum und für wen der „Unsinn von Rankings "Sinn macht. **ARL**, 1(2001), 1-3.

DASGUPTA, P. S., & HEAL, G. M., 1979 Economic theory and exhaustible resources. Cambridge University Press.

DAVIES, G. R., 2013 Appraising weak and strong sustainability: Searching for a middle ground. **Consilience**(10), 111-124.

DE JONG, M., JOSS, S., SCHRAVEN, D., ZHAN, C., & WEIJNEN, M., 2015 Sustainable–smart–resilient–low carbon–eco–knowledge cities

DE LA FUENTE, A., & DOMÉNECH, R., 2006 Human capital in growth regressions: how much difference does data quality make? **Journal of the European Economic Association**, 4(1), 1-36.

DE PRATO, G., & NEPELSKI, D., 2014 **Mapping the European ICT Poles of Excellence: The Atlas of ICT Activity in Europe.** JRC Scientific and Policy Reports EUR, 26579.

DE RASSENFOSSE, G., & DE LA POTTERIE, B. V. P., 2009 A policy insight into the R&D–patent relationship. **Research Policy**, 38(5), 779-792.

DE SHERBININ, A., REUBEN, A., LEVY, M., & JOHNSON, L., 2013 **Indicators in practice: How environmental indicators are being used in policy and management contexts.** Yale and Columbia Universities, New Haven and New York.

DE WIJS, L., WITTE, P., & GEERTMAN, S., 2016 How smart is smart? Theoretical and empirical considerations on implementing smart city objectives–a case study of Dutch railway station areas. Innovation: The European **Journal of Social Science Research**, 29(4), 424-441.

DEBNATH, A. K., CHIN, H. C., HAQUE, M. M., & YUEN, B., 2014 A methodological framework for benchmarking smart transport cities. **Cities**, 37, 47-56.

DECLARATION, R., 1992 Rio declaration on environment and development. Int.

DEDEURWAERDERE, T., 2013 Transdisciplinary sustainability science at higher education institutions: science policy tools for incremental institutional change. **Sustainability**, 5(9), 3783-3801.

DELAVALLADE, C., 2006 Corruption and distribution of public spending in developing countries. **Journal of economics and finance**, 30(2), 222-239.

DELBOSC, A., & CURRIE, G., 2011 Exploring the relative influences of transport disadvantage and social exclusion on well-being. **Transport Policy**, 18(4), 555-562.

DEMPSEY, N., BRAMLEY, G., POWER, S., & BROWN, C., 2011 The social dimension of sustainable development: Defining urban social sustainability. **Sustainable development**, 19(5), 289-300.

DEN BOER, M., 2002 Towards an accountability regime for an emerging European policing governance. **Policing & Society**, 12(4), 275-289.

DENG, T., LI, X., & MA, M., 2017 Evaluating impact of air pollution on China's inbound tourism industry: A spatial econometric approach. **Asia Pacific Journal of Tourism Research**, 22(7), 771-780.

DERLUKIEWICZ, N., 2014 Development of smart and sustainable economy in the European Union. **European Journal of Sustainable Development**, 3(4).

DETOTTO, C., & OTRANTO, E., 2010 Does crime affect economic growth? **Kyklos**, 63(3), 330-345.

DICKINSON, J. E., & ROBBINS, D., 2008 Representations of tourism transport problems in a rural destination. **Tourism Management**, 29(6), 1110-1121.

DIESENDORF, M., 2000 Sustainability and sustainable development. **Sustainability**: The corporate challenge of the 21st century, Sydney: Allen & Unwin, chap. 2, 19-37.

DIRKS, S., KEELING, M., & DENCIK, J., 2009 **How smart is your city?: Helping cities measure progress.** IBM Institute for Business Value, IBM Global Business Services, New York.

DISANO, J., 2002 **Indicators of sustainable development: Guidelines and methodologies**. United Nations Department of Economic and Social Affairs, New York.

DIZDAROGLU, D., 2015 Developing micro-level urban ecosystem indicators for sustainability assessment. **Environmental Impact Assessment Revie**w, 54, 119-124.

DIZDAROGLU, D., & YIGITCANLAR, T., 2016 Integrating urban ecosystem sustainability assessment into policy-making: Insights from the Gold Coast City. **Journal of Environmental Planning and Management**, 59(11), 1982-2006.

DJANKOV, S., 2009 **The regulation of entry: A survey.** The World Bank Research Observer, 24(2), 183-203.

DOBSON, A., 1996 Environment sustainabilities: An analysis and a typology. **Environmental politics**, 5(3), 401-428.

DOBSON, A., 2003 **Citizenship and the Environment.** OUP Oxford.

DOERR, S., 2020 Could housing booms undermine productivity growth? **SUERF Policy Briefs**(40).

DOHERTY, D., & WOLAK, J., 2012 When do the ends justify the means? Evaluating procedural fairness. **Political Behavior**, 34(2), 301-323.

DOKURNO, Z., & FIEDOR, B., 2016 Sustainable Development as the Concept of World Economy Development from Contemporary Macroeconomics Perspective. Gospodarka Narodowa. **The Polish Journal of Economics**, 282(2), 5-24.

DOMENECH, J., ESCAMILLA, R., & ROIG-TIERNO, N., 2016 Explaining knowledge-intensive activities from a regional perspective. **Journal of Business Research**, 69(4), 1301-1306.

DOWNS, A., 2005 Smart growth: Why we discuss it more than we do it. **Journal of the American Planning Association**, 71(4), 367-378.

DRAZKIEWICZ, A., CHALLIES, E., & NEWIG, J., 2015 Public participation and local environmental planning: Testing factors influencing decision quality and implementation in four case studies from Germany. **Land use policy**, 46, 211-222.

DRLJAČA, M., 2015 **The transition from linear to circular economy (concept of efficient waste management).** Iii. International conference, proceedings book quality system condition for successful business and competitiveness, association for quality and standardization of serbia, vrnjačka banja.

DRÖES, M. I., & RIETVELD, P., 2015 Rail-based public transport and urban spatial structure: The interplay between network design, congestion and urban form. **Transportation Research Part B: Methodological**, 81, 421-439.

DU PISANI, J. A., 2006 Sustainable development–historical roots of the concept. **Environmental sciences**, 3(2), 83-96.

DU, Q., & KANG, J., 2016 Tentative ideas on the reform of exercising state ownership of natural resources: Preliminary thoughts on establishing a state-owned natural resources supervision and administration commission. **Jiangxi Social Science**, 6, 160.

DUBOW, T., DEVAUX, A., & MANVILLE, C., 2017 **Civic Engagement: How Can Digital Technology Encourage Greater Engagement in Civil Society?** RAND Europe.

DUR, F., & YIGITCANLAR, T., 2015 Assessing land-use and transport integration via a spatial composite indexing model. **International**

**Journal of Environmental Science and Technology**, 12(3), 803-816.

DURANTON, G., & TURNER, M. A., 2012 Urban growth and transportation. **Review of Economic Studies**, 79(4), 1407-1440.

DUSTDAR, S., NASTIĆ, S., & ŠĆEKIĆ, O., 2017 Smart cities. **The Internet of Things, People and Systems.**

DVIR, R., & PASHER, E., 2004 Innovation engines for knowledge cities: an innovation ecology perspective. **Journal of knowledge management.**

DVOULETÝ, O., 2017 What is the relationship between entrepreneurship and unemployment in Visegrad countries? **Central European Business Review**, 6(2), 42-53.

DVOULETÝ, O., & MAREŠ, J., 2016 Determinants of Regional Entrepreneurial Activity in the Czech Republic. **Economic Studies & Analyses**/Acta VSFS, 10(1).

DVOULETÝ, O., & MAREŠ, J., 2016 Relationship between unemployment and entrepreneurial activity: Evidence found among Visegrad countries. **Innovation Management, Entrepreneurship and Corporate Sustainability** (IMECS 2016), 146-156.

DWIVEDI, O. P., 1967 Bureaucratic corruption in developing countries. **Asian Survey**, 245-253.

EAST, M., & WHITE, R. M., 2016 **Reflecting on the emergence of the UN sustainable development goals: a call for action in Scotland.** Report for Scottish Government and COSLA, 55.

EDQUIST, C., HOMMEN, L., & MCKELVEY, M. D., 2001 **Innovation and employment: Process versus product innovation.** Edward Elgar Publishing.

EGER, J. M., 2009 Smart growth, smart cities, and the crisis at the pump a worldwide phenomenon. **The Journal of E-Government Policy and Regulation**, 32(1), 47-53.

EHRLICH, P. R., 1968 **The population bomb.** New York, 72-80.

EHRLICH, P. R., & EHRLICH, A. H., 1990 The population explosion.

EKDAHL, P., & TROJER, L., 2002 Digital divide: Catch up for what? Gender, **Technology and Development**, 6(1), 1-20.

EKINS, P., SIMON, S., DEUTSCH, L., FOLKE, C., & DE GROOT, R., 2003 A framework for the practical application of the concepts of critical natural capital and strong sustainability. **Ecological economics**, 44(2-3), 165-185.

EL GHAK, T., GDAIRIA, A., & ABASSI, B., 2021 High-tech entrepreneurship and total factor productivity: The case of innovation-driven economies. **Journal of the knowledge economy**, 12(3), 1152-1186.

ELDER, M., BENGTSSON, M., & AKENJI, L., 2016 An optimistic analysis of the means of implementation for sustainable development goals: Thinking about goals as means. **Sustainability**, 8(9), 962.

ELKINGTON, J., 1997 The triple bottom line. Environmental management: **Readings and cases**, 2, 49-66.

ELKINGTON, J., 1998 Accounting for the triple bottom line. **Measuring business excellence.**

ELMAGHRABY, A. S., & LOSAVIO, M. M., 2014 Cyber security challenges in Smart Cities: Safety, security and privacy. **Journal of advanced research**, 5(4), 491-497.

ESCAMILLA SOLANO, S., PLAZA CASADO, P., & FLORES UREBA, S., 2017 Smart cities and sustainable development. a case study. **Sustainable Smart Cities** (pp. 65-77). Springer.

ESCOBAR, A., 1996 Construction nature: Elements for a post-structuralist political ecology. **Futures**, 28(4), 325-343.

ESCOBAR, A., 2005 Imagining a post-development era. **Power of development** (pp. 221-238). Routledge.

ESPEY, J., WALĘCIK, K., & KÜHNER, M., 2015 Follow-up and Review of the SDGs: Fulfilling our commitments. **JSTOR**.

EVANS, J., & REPPER, J., 2000 Employment, social inclusion and mental health. **Journal of psychiatric and mental health nursing**, 7(1), 15-24.

FADEYI, O., KREJCAR, O., MARESOVA, P., KUCA, K., BRIDA, P., & SELAMAT, A., 2019 Opinions on sustainability of smart cities in the context of energy challenges posed by cryptocurrency mining. **Sustainability**, 12(1), 169.

FAID, G., TARIQ, M. M., ISHTIAQ, A., ZEYNVAND, V. L., MEYER, D. F., & MÁTÉ, D., 2020 The nexus of E-government and increased productivity relative to income level comparison. Business, **Management and Economics Engineering**, 18(1), 88-105.

FAID, G., TARIQ, M. M., ISHTIAQ, A., ZEYNVAND, V. L., MEYER, D. F., & MÁTÉ, D., 2020 The nexus of E-government and increased productivity relative to income level comparison. Business, **Management and Economics Engineering**, 18(1), 88-105.

FALCK, O., HEIMISCH, A., & WIEDERHOLD, S., 2016 **Returns to ICT skills.** IEB.

FAN, Y., FANG, C., & ZHANG, Q., 2019 Coupling coordinated development between social economy and ecological environment in Chinese provincial capital cities-assessment and policy implications. **Journal of cleaner production**, 229, 289-298.

FANKHAESER, S., SEHLLEIER, F., & STERN, N., 2008 Climate change, innovation and jobs. **Climate policy**, 8(4), 421-429.

FARVAR, M. T., & GLAESER, B., 1979 Politics of ecodevelopment. Berlin International Institute of Environment and Society, Germany.

FAUCHEUX, S., MUIR, E., & O'CONNOR, M., 1997 Neoclassical natural capital theory and" weak" indicators for sustainability. **Land economics,** 528-552.

FEDERICI, A., & MAZZITELLI, A., 2005 **Dynamic factor analysis with Stata**. 2nd Italian Stata users group meeting, Milano.

FEHSKE, A., FETTWEIS, G., MALMODIN, J., & BICZOK, G., 2011 The global footprint of mobile communications: The ecological and economic perspective. **IEEE communications magazine**, 49(8), 55-62.

FEHSKE, A., FETTWEIS, G., MALMODIN, J., & BICZOK, G., 2011 The global footprint of mobile communications: The ecological and economic perspective. **IEEE communications magazine**, 49(8), 55-62.

FERNÁNDEZ-GÜELL, J.-M., COLLADO-LARA, M., GUZMÁN-ARANA, S., & FERNÁNDEZ-ANEZ, V., 2016 Incorporating a systemic and foresight approach into smart city initiatives: the case of Spanish cities. **Journal of urban technology**, 23(3), 43-67.

FERRARIS, A., SANTORO, G., & PAPA, A., 2018 The cities of the future: Hybrid alliances for open innovation projects. **Futures**, 103, 51-60.

FERRO, E., CAROLEO, B., LEO, M., OSELLA, M., & PAUTASSO, E., 2013 **The role of ICT in smart cities governance.** Proceedings of 13th international conference for e-democracy and open government. Donau-Universität Krems.

FIELD, B. C., 1994 **Environmental Economics: An Introduction**. McGraw-Hill, Inc., New York.

FILLIS, I., & RENTSCHLER, R., 2010 The role of creativity in entrepreneurship. **Journal of enterprising culture**, 18(01), 49-81.

FISCHBACH, R. L., & HERBERT, B., 1997 Domestic violence and mental health: correlates and conundrums within and across cultures. **Social science & medicine**, 45(8), 1161-1176.

FISCHER, C., & HEUTEL, G., 2013 Environmental macroeconomics: Environmental policy, business cycles, and directed technical change. **Annu. Rev. Resour. Econ**., 5(1), 197-210.

FLEISCHER, A., & BUCCOLA, S., 2002 War, terror, and the tourism market in Israel. **Applied Economics**, 34(11), 1335-1343.

FOLKE, C., HAMMER, M., & JANSSON, A.-M., 1991 Life-support value of ecosystems: a case **study of the Baltic Sea Region.** Ecological economics, 3(2), 123-137.

FONT, X., GARAY, L., & JONES, S., 2016 Sustainability motivations and practices in small tourism enterprises in European protected areas. **Journal of cleaner production**, 137, 1439-1448.

FORS, H., MOLIN, J. F., MURPHY, M. A., & VAN DEN BOSCH, C. K., 2015 User participation in urban green spaces–For the people or the parks? **Urban Forestry & Urban Greening**, 14(3), 722-734.

FRANK, D. J., HIRONAKA, A., & SCHOFER, E., 2000 The nation-state and the natural environment over the twentieth century. **American sociological review**, 96-116.

FRANZESE, R. J., 2001 **Institutional and sectoral interactions in monetary policy and wage/price-bargaining.** In (Vol. 1, pp. 104-144): Oxford University Press Oxford.

FREDERICK, K. D. G. P. H., 1989 Water resources and climate change. **Climate Change Economics and Policy** (pp. 79-86). Routledge.

FREEMAN, C., CLARK, J., & SOETE, L., 1982 **Unemployment and technical innovation: a study of long waves and economic development.** Westport, Conn. Greenwood Press.

FREEMAN, K., & SMITH, N., 2014 Understanding the relationship between crime victimisation and mental health: a longitudinal analysis of population data. **Crime and Justice Bulletin** (177), 1-16.

FREEMAN, L. C., 1978 Centrality in social networks conceptual clarification. **Social networks**, 1(3), 215-239.

FREEMAN, R. B., 1999 **The economics of crime.** Handbook of labour economics, 3, 3529-3571.

FREUND, C., & RIJKERS, B., 2014 Episodes of unemployment reduction in rich, middle-income and transition economies. **Journal of Comparative Economics**, 42(4), 907-923.

FRITSCH, M., S. KRITIKOS, A., & SORGNER, A., 2015 Why did self-employment increase so strongly in Germany? **Entrepreneurship & Regional Development**, 27(5-6), 307-333.

FUKUDA-PARR, S., 2016 From the Millennium Development Goals to the Sustainable Development Goals: shifts in purpose, concept, and politics of global goal setting for development. **Gender & Development**, 24(1), 43-52.

GABRYS, J., 2007 Automatic sensation: environmental sensors in the digital city. **The Senses and Society**, 2(2), 189-200.

GABRYS, J., 2014 Programming environments: Environmentality and citizen sensing in the smart city. **Environment and Planning D: Society and Space**, 32(1), 30-48.

GAJENDRA, S., XI, B., & WANG, Q., 2012 E-government: Public participation and ethical issues. **Journal of e-Governance**, 35(4), 195-204.

GALDON-CLAVELL, G., 2013 (Not so) smart cities?: The drivers, impact and risks of surveillance-enabled smart environments. **Science and Public Policy**, 40(6), 717-723.

GALLOPÍN, G. C., 2003 **A systems approach to sustainability and sustainable development**. ECLAC.

GALPERINA, L. P., GIRENKO, A. T., & MAZURENKO, V. P., 2016 The concept of smart economy as the basis for sustainable development of Ukraine. **International Journal of Economics and Financial Issues**, 6(8), 307-314.

GAN, J., & SMITH, C., 2011 Drivers for renewable energy: A comparison among OECD countries. **Biomass and Bioenergy**, 35(11), 4497-4503.

GAN, J., & SMITH, C., 2011 Drivers for renewable energy: A comparison among OECD countries. **Biomass and Bioenergy**, 35(11), 4497-4503.

GANI, A., & CLEMES, M. D., 2017 The main determinants effecting international visitor arrivals in New Zealand: Some empirical evidence. **Tourism Economics**, 23(5), 921-940.

GANJU, N. K., KIRWAN, M. L., DICKHUDT, P. J., GUNTENSPERGEN, G. R., CAHOON, D. R., & KROEGER, K. D., 2015 Sediment transport-based metrics of wetland stability. **Geophysical Research Letters**, 42(19), 7992-8000.

GARAU, C., & PAVAN, V. M., 2018 Evaluating urban quality: Indicators and assessment tools for smart sustainable cities. Sustainability, 10(3), 575.

GARCÍA-FUENTES, M. Á., QUIJANO, A., DE TORRE, C., GARCÍA, R., COMPERE, P., DEGARD, C., & TOMÉ, I., 2017 European cities characterization as basis towards the replication of a smart and sustainable urban regeneration model. **Energy Procedia**, 111, 836-845.

GARGIULO MORELLI, V., WEIJNEN, M., VAN BUEREN, E., WENZEL, I., DE REUVER, M., & SALVATI, L., 2013 Towards intelligently-sustainable cities? From intelligent and knowledge city programmes to the achievement of urban sustainability. **TeMA Journal of Land Use, Mobility and Environment**, 6(1), 73-86.

GASCO-HERNANDEZ, M., NASI, G., CUCCINIELLO, M., & HIEDEMANN, A. M., 2022 The role of organizational capacity to foster digital transformation in local governments: The case of three European smart cities. **Urban Governance**.

GAZZOLA, P., DEL CAMPO, A. G., & ONYANGO, V., 2019 Going green vs going smart for sustainable development: Quo vadis? **Journal of cleaner production**, 214, 881-892.

GEORGESCU, R., N.,1971 **The entropy law and the economic process.** Cambridge-mass, Harvard university press.

GERBER, A. S., HUBER, G. A., BIGGERS, D. R., & HENDRY, D. J., 2017 Can political participation prevent crime? Results from a field experiment about citizenship, participation, and criminality. **Political Behavior**, 39(4), 909-934.

GHAHRAMANPOURI, A., ABDULLAH, A. S., SEDAGHATNIA, S., & LAMIT, H., 2015 Urban social sustainability contributing factors in Kuala Lumpur Streets. **Procedia-Social and Behavioral Sciences**, 201, 368-376.

GHISELLINI, P., CIALANI, C., & ULGIATI, S., 2016 A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. **Journal of cleaner production**, 114, 11-32.

GIDDENS, A., 1994 **Beyond left and right: The future of radical politics**. Stanford University Press.

GIFFINGER, R., FERTNER, C., KRAMAR, H., & MEIJERS, E., 2007 City-ranking of European medium-sized cities. **Cent. Reg. Sci**. Vienna UT, 1-12.

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.

GIFFINGER, R., HAINDLMAIER, G., & KRAMAR, H., 2010 The role of rankings in growing city competition. **Urban Research & Practice**, 3(3), 299-312.

GIL-GARCIA, J. R., HELBIG, N., & OJO, A., 2014 Being smart: Emerging technologies and innovation in the public sector. **Government information quarterly**, 31, I1-I8.

GIL-GARCÍA, J. R., & PARDO, T. A., 2005 E-government success factors: Mapping practical tools to theoretical foundations. **Government information quarterly**, 22(2), 187-216.

GIL-GARCIA, J. R., PARDO, T. A., & NAM, T., 2015 What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization. **Information Polity**, 20(1), 61-87.

GIL-GARCIA, J. R., PARDO, T. A., & NAM, T., 2016 A comprehensive view of the 21st century city: Smartness as technologies and innovation in urban contexts. **In Smarter as the new urban agenda** (pp. 1-19). Springer.

GILLESPIE, S., & VAN DEN BOLD, M., 2017 Agriculture, food systems, and nutrition: meeting the challenge. **Global Challenges**, 1(3), 1600002.

GILMAN, N., 2018 Modernization theory never dies. **History of Political Economy**, 50(S1), 133-151.

GIRARDI, P., & TEMPORELLI, A., 2017 Smartainability: a methodology for assessing the sustainability of the smart city. **Energy Procedia**, 111, 810-816.

GIULIODORI, A., BERRONE, P., & RICART, J. E., 2022 Where smart meets sustainability: The role of Smart Governance in achieving the Sustainable Development Goals in cities. **BRQ Business Research Quarterly**.

GLAESER, E. L., & BERRY, C. R., 2006 **Why are smart places getting smarter.** Rappaport Institute/Taubman Center Policy Brief, 2.

GLASMEIER, A., & CHRISTOPHERSON, S., 2015 **Thinking about smart cities.** In (Vol. 8, pp. 3-12): Oxford University Press UK.

GOEL, R. K., & SAUNORIS, J. W., 2017 Dynamics of knowledge spillovers from patents to entrepreneurship: Evidence across entrepreneurship types. **Contemporary Economic Policy**, 35(4), 700-715.

GÓMEZ-BAGGETHUN, E., & NAREDO, J. M., 2015 In search of lost time: the rise and fall of limits to growth in international sustainability policy. **Sustainability Science**, 10(3), 385-395.

GONG, W., LI, Z. G., & STUMP, R. L., 2007 Global internet use and access: cultural considerations. **Asia Pacific Journal of Marketing and Logistics.**

GOODLAND, R., 1995 The concept of environmental sustainability. **Annual review of ecology and systematics**, 26(1), 1-24.

GOODLAND, R., & DALY, H., 1996 Environmental sustainability: universal and non-negotiable. **Ecological applications**, 6(4), 1002-1017.

GOODWIN, N. R., HARRIS, J. M., & KRISHNAN, R., 1995 **A Survey of Ecological Economics.** Island Press.

GOSSLING-GOIDSMITHS, J., 2018 **Sustainable development goals and uncertainty visualization**. Unpublished master's thesis]. University of Twente.

GOVINDARAJAN, V., 2007 **The importance of strategic innovation**. http:/www. vijaygovindarajan. com/2006/03/the_importance_of_strategic_in. htm.

GOVINDARAJAN, V., & RAMAMURTI, R., 2011 Reverse innovation, emerging markets, and global strategy. **Global strategy journal**, 1(3-4), 191-205.

GOWDY, J. M., 1997 The value of biodiversity: markets, society, and ecosystems. **Land economics**, 25-41.

GOZGOR, G., LAU, C. K. M., ZENG, Y., & LIN, Z., 2019 The effectiveness of the legal system and inbound tourism. **Annals of tourism research**, 76, 24-35.

GRADSTEIN, M., 2003 **Governance and economic growth** (Vol. 3098). World Bank Publications.

GRAHAM, S. J., & SICHELMAN, T., 2008 **Why do start-ups patent.** Berkeley Tech. LJ, 23, 1063.

GRANT, R. M., 1991 The resource-based theory of competitive advantage: implications for strategy formulation. **California management review**, 33(3), 114-135.

GRASSI, E., & DI CINTIO, M., 2012 **Uncertainty, flexible labour relations and R&D expenditure**, EERI Research Paper Series, No. 13/2013, Economics and Econometrics Research Institute (EERI), Brussels.

GREENFIELD, A., 2013 **Against the Smart City: A Pamphlet.** This is Part I of" The City is Here to Use". Do projects.

GREENWOOD, D. T., & HOLT, R. P., 2016 Sustainable development in affluent countries and the neo-institutionalist synthesis. **Journal of Economic Issues**, 50(3), 647-666.

GREGORIO, J. D., & LEE, J. W., 2002 Education and income inequality: new evidence from cross-country data. **Review of income and wealth**, 48(3), 395-416.

GREW, R., 1980 More on modernization. **Journal of Social History**, 14(2), 179-187.

GRIFFINGER, R., FERTNER, C., KRAMAR, H., KALASEK, R., PICHLER-MILANOVIĆ, N., & MEIJERS, E., 2007 **Smart cities: Ranking of European medium-sized cities, final report**. Centre of Regional Science, Vienna TU.

GRIGGS, D., SMITH, M. S., ROCKSTRÖM, J., ÖHMAN, M. C., GAFFNEY, O., GLASER, G., KANIE, N., NOBLE, I., STEFFEN, W., & SHYAMSUNDAR, P., 2014 An integrated framework for sustainable development goals. **Ecology and society**, 19(4).

GRILICHES, Z., 1988 Productivity puzzles and R&D: Another nonexplanation. **Journal of Economic Perspectives**, 2(4), 9-21.

GROSSMAN, G. M., & HELPMAN, E., 1991 Trade, knowledge spillovers, and growth. European economic review, 35(2-3), 517-526.

GROSSMAN, G. M., & KRUEGER, A. B., 1991 **Environmental impacts of a North American free trade agreement**. National Bureau of economic research Cambridge, Mass., USA.

GROSSMAN, G. M., & KRUEGER, A. B., 1995 Economic growth and the environment. **The Quarterly Journal of Economics**, 110(2), 353-377.

GUETZKOW, J., 2002 **How the arts impact communities.** Centre for arts and cultural policy studies, 7-8.

GUPTA, S., DAVOODI, H., & ALONSO-TERME, R., 2002 Does corruption affect income inequality and poverty? **Economics of governance**, 3(1), 23-45.

GURUNG, D. B., & SEELAND, K., 2011 Ecotourism benefits and livelihood improvement for sustainable development in the nature conservation areas of Bhutan. **Sustainable development**, 19(5), 348-358.

GUTIÉRREZ-ROMERO, R., & MÉNDEZ-ERRICO, L., 2017 **Does inequality foster or hinder the growth of entrepreneurship in the long run? In Research on economic inequality.** Emerald Publishing Limited.

HAARSTAD, H., 2016 — Who is driving the ‘smart city’agenda? Assessing smartness as a governance strategy for cities in Europe. **Services and the green economy** (pp. 199-218). Springer.

HALL, C. M., & WILLIAMS, A. M., 2019 — **Tourism and innovation.** Routledge.

HALL, P. A., & SOSKICE, D., 2001 — **An introduction to varieties of capitalism.** op. cit, 21-27.

HALL, R. E., BOWERMAN, B., BRAVERMAN, J., TAYLOR, J., TODOSOW, H., & VON WIMMERSPERG, U., 2000 — **The vision of a smart city.** 2nd International Life Extension Technology Workshop Paris, France

HALL, R. P., 2006 — Understanding and applying the concept of sustainable development to transportation planning and decision-making in the US Massachusetts Institute of Technology.

HALLER, M., LI, M.-H., & MOSSBERGER, K., 2011 — **Does e-government use contribute to citizen engagement with government and community?** Apsa 2011 annual meeting paper.

HALVARSSON, D., KORPI, M., & WENNBERG, K., 2018 — Entrepreneurship and income inequality. **Journal of Economic Behavior & Organization**, 145, 275-293.

HAMANN, R., & ACUTT, N., 2003 — How should civil society (and the government) respond to'corporate social responsibility'? A critique of business motivations and the potential for partnerships. **Development Southern Africa**, 20(2), 255-270.

HAMILTON, A., MITCHELL, G., & YLI-KARJANMAA, S., 2002 — The BEQUEST toolkit: a decision support system for urban sustainability. **Building Research & Information**, 30(2), 109-115.

HARGITTAI, E., 2003 — **The digital divide and what to do about it.** New economy handbook, 2003, 821-839.

HARRIS, J. M., 2000 — Basic principles of sustainable development. **Dimensions of Sustainable Development**, 21-41.

HARRIS, J. M., 2013 — The macroeconomics of development without throughput growth. **Innovations in Sustainable Consumption.** Edward Elgar Publishing.

HARRISON, C., ECKMAN, B., HAMILTON, R., HARTSWICK, P., KALAGNANAM, J., — Foundations for smarter cities. **IBM Journal of research and development**, 54(4), 1-16.

PARASZCZAK, J., & WILLIAMS, P., 2010

HARTIG, T., MITCHELL, R., DE VRIES, S., & FRUMKIN, H., 2014 Nature and health. **Annual review of public health**, 35, 207-228.

HARTWICK, J. M., 1977 Intergenerational equity and the investing of rents from exhaustible resources. **The Economics of Sustainability** (pp. 63-65). Routledge.

HASSAN, Z., & BASIT, A., 2018 Ease of doing business and its impact on inward FDI. Hossain, MT, Hassan, Z., Shafiq, S., & Basit, A.(2018). Ease of Doing Business and Its Impact on Inward FDI. **Indonesian Journal of Management and Business Economics**, 1(1), 52-65.

HAUNER, D., & KYOBE, A., 2010 **Determinants of government efficiency.** World Development, 38(11), 1527-1542.

HAYTHORNTHWAITE, C., 2005 Social networks and Internet connectivity effects. **Information, Community & Society**, 8(2), 125-147.

HEDIGER, W., 1999 Reconciling "weak" and "strong" sustainability. **International Journal of Social Economics.**

HEDIGER, W., 2000 Sustainable development and social welfare. **Ecological economics**, 32(3), 481-492.

HEDIGER, W., 2006 Weak and strong sustainability, environmental conservation and economic growth. **Natural Resource Modeling**, 19(3), 359-394.

HEMLIN, S., OLSSON, L., & DENTI, L., 2013 **Creativity in R & D. In Handbook of research on creativity.** Edward Elgar Publishing.

HENS, L., 2005 **The Rio declaration on environment and development. Regional sustainable development review: Africa.** Oxford, UK, Eolss Publishers.

HESS, D. J., & COLLINS, B. M., 2018 Climate change and higher education: Assessing factors that affect curriculum requirements. **Journal of cleaner production**, 170, 1451-1458.

HEUSINKVELD, B. G., STEENEVELD, G. V., VAN HOVE, L., JACOBS, C., & HOLTSLAG, A., 2014 Spatial variability of the Rotterdam urban heat island as influenced by urban land use. **Journal of Geophysical Research: Atmospheres**, 119(2), 677-692.

HICKS, J. R., 1939 The foundations of welfare economics. **The economic journal**, 49(196), 696-712.

HIGÓN, D. A., 2012 The impact of ICT on innovation activities: Evidence for UK SMEs. **International Small Business Journal**, 30(6), 684-699.

HILLENBRAND, C., 2005 **Public libraries as developers of social capital.** Australasian public libraries and information services, 18(1), 4-12.

HILTY, L. M., KÖHLER, A., VON SCHÉELE, F., ZAH, R., & RUDDY, T., 2006 **Rebound effects of progress in information technology**. Poiesis & Praxis, 4(1), 19-38.

HIRSCH HADORN, G., 1999 Nachhaltige Entwicklung und der Wert der Natur. **GAIA-Ecological Perspectives for Science and Society**, 8(4), 269-274.

HJALAGER, A.-M., 2010 A review of innovation research in tourism. **Tourism Management**, 31(1), 1-12.

HO, C., & RASHID, H., 2011 Macroeconomic and country specific determinants of FDI. **The Business Review**, 18(1), 219-226.

HOFFMANN, R., LEE, C. G., RAMASAMY, B., & YEUNG, M., 2005 FDI and pollution: a granger causality test using panel data. Journal of International Development: **The Journal of the Development Studies Association**, 17(3), 311-317.

HÖJER, M., & WANGEL, J., 2015 Smart sustainable cities: definition and challenges. **ICT innovations for sustainability** (pp. 333-349). Springer.

HOLDEN, M., 2013 Sustainability indicator systems within urban governance: Usability analysis of sustainability indicator systems as boundary objects. **Ecological indicators**, 32, 89-96.

HOLL, A., 2016 Highways and productivity in manufacturing firms. **Journal of urban economics**, 93, 131-151.

HOLLANDS, R. G., 2008 Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? **City**, 12(3), 303-320.

HOLLING, C. S., 1973 Resilience and stability of ecological systems. **Annual review of ecology and systematics**, 4(1), 1-23.

HOLMES, L., 2009 Crime, organised crime and corruption in post-communist Europe and the CIS. **Communist and Post-Communist Studies**, 42(2), 265-287.

HOLMES, T., & SCOONES, I., 2000 Participatory environmental policy processes: experiences from North and South.

HOLT, R. P., 2005 Post-Keynesian economics and sustainable development. International **Journal of Environment, Workplace and Employment**, 1(2), 174-186.

HONG, S., & NADLER, D., 2012 Which candidates do the public discuss online in an election campaign?: The use of social media by 2012 presidential candidates and its impact on candidate salience. **Government information quarterly**, 29(4), 455-461.

HOOGHE, M., VISSERS, S., STOLLE, D., & MAHÉO, V.-A., 2010 The potential of Internet mobilization: An experimental study on the effect of Internet and face-to-face mobilization efforts. **Political Communication**, 27(4), 406-431.

HOORNWEG, D., SUGAR, L., & TREJOS GÓMEZ, C. L., 2011 Cities and greenhouse gas emissions: moving forward. **Environment and urbanization**, 23(1), 207-227.

HOPPE, T., VAN DER VEGT, A., & STEGMAIER, P., 2016 Presenting a framework to analyze local climate policy and action in small and medium-sized cities. **Sustainability**, 8(9), 847.

HOPWOOD, B., MELLOR, M., & O'BRIEN, G., 2005 Sustainable development: mapping different approaches. **Sustainable development**, 13(1), 38-52.

HOUGHTON, J. W., 2015 **ICT, the Environment, and Climate Change.** The International Encyclopedia of Digital Communication and Society, 1-13.

HU, M., SU, Y., & YE, W., 2019 Promoting or inhibiting: The role of housing price in entrepreneurship. **Technological Forecasting and Social Change**, 148, 119732.

HU, Q., & ZHENG, Y., 2021 Smart city initiatives: A comparative study of American and Chinese cities. **Journal of Urban Affairs**, 43(4), 504-525.

HUANG, L., WU, J., & YAN, L., 2015 Defining and measuring urban sustainability: a review of indicators. **Landscape ecology**, 30(7), 1175-1193.

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.

HUOVILA, A., PENTTINEN, T., AIRAKSINEN, M., PINTO-SEPPÄ, I., PIIRA, K., & PENTTINEN, T., 2016 **Smart city performance measurement system.** Proceedings of the 41th IAHS world congress sustainability innovation for the future, algarve, Portugal.

INAYATULLAH, S., 2011 City futures in transformation: Emerging issues and case studies. **Futures**, 43(7), 654-661.

INSKEEP, E., 1991 **Tourism planning: An integrated and sustainable development approach**. John Wiley & Sons.

IRAWAN, T., 2014 ICT and economic development: comparing ASEAN member states. **International Economics and Economic Policy**, 11(1), 97-114.

ISLAM, M. M., & EHSAN, M., 2015 Understanding e-governance: A theoretical approach. In Public Affairs and Administration: Concepts, Methodologies, Tools, and Applications (pp. 1811-1823). **IGI Global.**

ISLAM, M. R., & MCGILLIVRAY, M., 2020 Wealth inequality, governance and economic growth. **Economic Modelling**, 88, 1-13.

ISLAM, R., 2006 Does more transparency go along with better governance? **Economics & Politics**, 18(2), 121-167.

ISMAGILOVA, E., HUGHES, L., RANA, N. P., & DWIVEDI, Y. K., 2020 — Security, privacy and risks within smart cities: Literature review and development of a smart city interaction framework. **Information Systems Frontier**s, 1-22.

ITU, I., 2017 — **Measuring the Information Society Report: ICT Country profiles.** Geneva Switzerland: International Telecommunication Union.

IVANOVA, M., 2007 — Designing the United Nations Environment Programme: a story of compromise and confrontation. International Environmental Agreements: **Politics, Law and Economics**, 7(4), 337-361.

IVANOVA, M., 2013 — The contested legacy of Rio+ 20. **Global Environmental Politics**, 13(4), 1-11.

JABAREEN, Y., 2004 — A knowledge map for describing variegated and conflict domains of sustainable development. **Journal of Environmental Planning and Management**, 47(4), 623-642.

JABAREEN, Y. R., 2006 — Sustainable urban forms: Their typologies, models, and concepts. **Journal of planning education and research**, 26(1), 38-52.

JAEGER, P. T., & BERTOT, J. C., 2011 — Responsibility rolls down: Public libraries and the social and policy obligations of ensuring access to e-government and government information. **Public Library Quarterly**, 30(2), 91-116.

JANSSEN, M., & KUK, G., 2016 — The challenges and limits of big data algorithms. **Technocratic governance**. Vol. 33, pp. 371-377, Elsevier.

JENKINS, S. P., & CAPPELLARI, L., 2007 — Summarizing multiple deprivation indicators.

JENSEN, R., 2007 — The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. **The Quarterly Journal of Economics**, 122(3), 879-924.

JEROME, A., 2011 — Infrastructure, economic growth and poverty reduction in Africa. **Journal of infrastructure development**, 3(2), 127-151.

JIAO, H., KOO, C. K., & CUI, Y., 2015 — Legal environment, government effectiveness and firms' innovation in China: examining the moderating influence of government ownership. **Technological Forecasting and Social Change**, 96, 15-24.

JOHNSON, W. A., 2010 — **Readers and reading culture in the high Roman Empire: a study of elite communities**. Oxford University Press.

JONES, B. F., 2014 — The human capital stock: a generalized approach. **American Economic Review**, 104(11), 3752-3777.

JONES, C. I., & KIM, J., 2018 A Schumpeterian model of top income inequality. **Journal of political Economy**, 126(5), 1785-1826.

JOSHI, S., SAXENA, S., & GODBOLE, T., 2016 Developing smart cities: An integrated framework. **Procedia Computer Science**, 93, 902-909.

JOSS, S., SENGERS, F., SCHRAVEN, D., CAPROTTI, F., & DAYOT, Y., 2019 The smart city as global discourse: Storylines and critical junctures across 27 cities. **Journal of urban technology**, 26(1), 3-34.

KALECKI, M., 1976 **Essays on developing economies.** Hassocks, Eng.: Harvester Press

KANIE, N., & BIERMANN, F., 2017 Governing through goals: Sustainable development goals as governance innovation. MIT Press.

KAPOOR, R., & LIM, K., 2007 The impact of acquisitions on the productivity of inventors at semiconductor firms: A synthesis of knowledge-based and incentive-based perspectives. **Academy of Management Journal**, 50(5), 1133-1155.

KÄRRHOLM, M., 2011 The scaling of sustainable urban form: A case of scale-related issues and sustainable planning in Malmö, Sweden. **European planning studies**, 19(1), 97-112.

KATES, R. W., CLARK, W. C., CORELL, R., HALL, J. M., JAEGER, C. C., LOWE, I., MCCARTHY, J. J., SCHELLNHUBER, H. J., BOLIN, B., & DICKSON, N. M., 2001 Sustainability science. **Science**, 292(5517), 641-642.

KAUFMANN, D., KRAAY, A., & ZOIDO, P., 1999 **Governance matters**. Available at SSRN 188568.

KAYANI, G. M., ASHFAQ, S., & SIDDIQUE, A., 2020 Assessment of financial development on environmental effect: implications for sustainable development. J**ournal of cleaner production**, 261, 120984.

KAYSEN, C., 1972 The computer that printed out W* O* L* F. **Foreign Affairs**, 50(4), 660-668.

KEITSCH, M., 2018 Structuring ethical interpretations of the sustainable development goals—Concepts, implications and progress. **Sustainability**, 10(3), 829.

KELLY, F. J., 2022 **COP26–time for action**. pp. 1-1: Springer.

KEMP, R., & FOXON, T., 2007 **Typology of eco-innovation.** Project Paper: Measuring Eco-Innovation, 5(1), 10-23.

KENNEDY, C., CUDDIHY, J., & ENGEL-YAN, J., 2007 The changing metabolism of cities. **Journal of industrial ecology**, 11(2), 43-59.

KENNEDY, C., PINCETL, S., & BUNJE, P., 2011 The study of urban metabolism and its applications to urban planning and design. **Environmental pollution**, 159(8-9), 1965-1973.

KENNY, C., 2009 Measuring corruption in infrastructure: Evidence from transition and developing countries. **The Journal of Development Studies**, 45(3), 314-332.

KENSKI, K., & STROUD, N. J., 2006 Connections between Internet use and political efficacy, knowledge, and participation. **Journal of broadcasting & electronic media**, 50(2), 173-192.

KENT JENNINGS, M., & ZEITNER, V., 2003 Internet use and civic engagement: A longitudinal analysis. **Public Opinion Quarterly**, 67(3), 311-334.

KHAN, M. A., 1995 Concepts, definitions and key issues in sustainable development: the outlook for the future.

KHANNA, M., SWINTON, S. M., & MESSER, K. D., 2018 Sustaining our natural resources in the face of increasing societal demands on agriculture: Directions for future research. **Applied Economic Perspectives and Policy**, 40(1), 38-59.

KIM, B. J., KAVANAUGH, A., & PEREZ-QUINONES, M., 2007 **Toward a model of political participation among young adults: the role of local groups and ICT use.** Proceedings of the 1st international conference on theory and practice of electronic governance

KIM, H. M., 2021 Smart cities beyond COVID-19. **Smart Cities for Technological and Social Innovation** (pp. 299-308). Elsevier.

KIM, H. M., SABRI, S., & KENT, A., 2021 Smart cities as a platform for technological and social innovation in productivity, sustainability, and livability: A conceptual framework. **Smart Cities for Technological and Social Innovation** (pp. 9-28). Elsevier.

KIM, K.-G., 2018 **Low-Carbon Smart Cities.** Springer.

KING, J. L., GURBAXANI, V., KRAEMER, K. L., MCFARLAN, F. W., RAMAN, K., & YAP, C.-S., 1994 Institutional factors in information technology innovation. **Information systems research**, 5(2), 139-169.

KIRCHHERR, J., REIKE, D., & HEKKERT, M., 2017 Conceptualizing the circular economy: An analysis of 114 definitions. **Resources, conservation and recycling**, 127, 221-232.

KITCHIN, R., LAURIAULT, T. P., & MCARDLE, G., 2015 Knowing and governing cities through urban indicators, city benchmarking and real-time dashboards. **Regional Studies, Regional Science**, 2(1), 6-28.

KLARIN, T., 2018 The concept of sustainable development: From its beginning to the contemporary issues. **Zagreb**

**International Review of Economics & Business**, 21(1), 67-94.

KLEINKNECHT, A., 1998 Is labour market flexibility harmful to innovation? **Cambridge Journal of Economics,** 22(3), 387-396.

KLEPPER, S., 2009 Spinoffs: A review and synthesis. **European Management Review**, 6(3), 159-171.

KLIMOVSKÝ, D., PINTERIČ, U., & ŠAPARNIENĖ, D., 2016 Human limitations to introduction of smart cities: Comparative analysis from two CEE cities. **Transylvanian review of administrative sciences**, 12(47), 80-96.

KLOPP, J. M., & PETRETTA, D. L., 2017 The urban sustainable development goal: Indicators, complexity and the politics of measuring cities. **Cities**, 63, 92-97.

KNACK, S. F., 2000 **Social capital and the quality of government: Evidence from the United States** (Vol. 2504). World Bank Publications.

KNÖBL, W., 2003 **Theories that won't pass away: The never-ending story.** Handbook of Historical Sociology. Washington: SAGE, 96-107.

KOMNINOS, N., 2008 **Intelligent cities and globalisation of innovation networks.** Routledge.

KOMNINOS, N., 2011 Intelligent cities: Variable geometries of spatial intelligence. **Intelligent Buildings International**, 3(3), 172-188.

KORHONEN, J., NUUR, C., FELDMANN, A., & BIRKIE, S. E., 2018 Circular economy as an essentially contested concept. **Journal of cleaner production**, 175, 544-552.

KORTEN, D. C., 1990 **Getting to the 21st century: Voluntary action and the global agenda**. Kumarian Press West Hartford, CT.

KOSTADINOVA, T., 2009 Abstain or rebel: Corruption perceptions and voting in East European elections. **Politics & Policy**, 37(4), 691-714.

KOTHARI, R., 1990 **Environment, technology and ethics**. Technology and Values: Essential Readings, 431-453.

KOTILOGLU, S., LAPPAS, T., PELECHRINIS, K., & REPOUSSIS, P., 2017 Personalized multi-period tour recommendations. **Tourism Management,** 62, 76-88.

KOURTIT, K., & NIJKAMP, P., 2012 Smart cities in the innovation age. Innovation: **The European Journal of Social Science Research**, 25(2), 93-95.

KOUTROUMPIS, P., LEIPONEN, A., & THOMAS, L. D., 2020 Markets for data. **Industrial and Corporate Change**, 29(3), 645-660.

KOŹLAK, A., & WACH, D., 2018 **Causes of traffic congestion in urban areas.** Case of Poland. SHS web of conferences.

KPODAR, K., & ANDRIANAIVO, M., 2011 **ICT, Financial Inclusion, and Growth Evidence from African Countries**. IMF Working Papers, 11(73), 1. https://doi.org/10.5089/9781455227068.001

KPODAR, M. K., & ANDRIANAIVO, M., 2011 I**CT, financial inclusion, and growth: Evidence from African countries.** International Monetary Fund.

KRAMERS, A., HÖJER, M., LÖVEHAGEN, N., & WANGEL, J., 2014 Smart sustainable cities–Exploring ICT solutions for reduced energy use in cities. **Environmental modelling & software**, 56, 52-62.

KRAUS, S., RICHTER, C., PAPAGIANNIDIS, S., & DURST, S., 2015 Innovating and exploiting entrepreneurial opportunities in smart cities: Evidence from Germany. **Creativity and innovation management**, 24(4), 601-616.

KRUEGER, A. O., 2000 **Economic policy reform: the second stage.** University of Chicago Press.

KUDO, H., 2008 Does e-government guarantee accountability in public sector? Experiences in Italy and Japan. **Public Administration Quarterly**, 93-120.

KUMAR, A., & ANBANANDAM, R., 2019 Development of social sustainability index for freight transportation system. **Journal of cleaner production**, 210, 77-92.

KUMAR, A., SAH, B., SINGH, A. R., DENG, Y., HE, X., KUMAR, P., & BANSAL, R., 2017 A review of multi criteria decision making (MCDM) towards sustainable renewable energy development. **Renewable and Sustainable Energy Reviews**, 69, 596-609.

KUMAR, H., SINGH, M. K., & GUPTA, M., 2019 A policy framework for city eligibility analysis: TISM and fuzzy MICMAC-weighted approach to select a city for smart city transformation in India. **Land use policy**, 82, 375-390.

KUMAR, P., AHMED, F., SINGH, R. K., & SINHA, P., 2018 Determination of hierarchical relationships among sustainable development goals using interpretive structural modeling. **Environment, Development and Sustainability**, 20(5), 2119-2137.

KUMAR, T. V., & DAHIYA, B., 2017 Smart economy in smart cities. **Smart economy in smart cities** (pp. 3-76). Springer.

KUMMITHA, R. K. R., 2019 Smart cities and entrepreneurship: An agenda for future research. **Technological Forecasting and Social Change**, 149, 119763.

KUZNETS, S., & MURPHY, J. T., 1966 **Modern economic growth: Rate, structure, and spread (Vol. 2).** Yale University Press New Haven.

KYBURZ-GRABER, R., HOFER, K., & WOLFENSBERGER, B., 2006 Studies on a socio-ecological approach to environmental education: a contribution to a critical position in the education for sustainable development discourse. **Environmental Education Research**, 12(1), 101-114.

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|---|---|
| LADNER, A., & PIANZOLA, J., (2010 | **Do voting advice applications have an effect on electoral participation and voter turnout? Evidence from the 2007 Swiss federal elections.** International conference on electronic participation. |
| LAMBSDORFF, J. G., 2003 | How corruption affects productivity. **Kyklos**, 56(4), 457-474. |
| LANCEE, B., & VAN DE WERFHORST, H. G., 2012 | Income inequality and participation: A comparison of 24 European countries. **Social science research**, 41(5), 1166-1178. |
| LATIEF, R., KONG, Y., PENG, Y., & JAVEED, S. A., 2020 | Conceptualizing pathways of sustainable development in the union for the Mediterranean countries with an empirical intersection of energy consumption and economic growth. International **Journal of Environmental Research and Public Health**, 17(15), 5614. |
| LAWN, P. A., 2000 | **Toward sustainable development: an ecological economics approach.** CRC Press. |
| LAZAROIU, G. C., & ROSCIA, M., 2012 | Definition methodology for the smart cities model. **Energy**, 47(1), 326-332. |
| LE BLANC, D., 2015 | Towards integration at last? The sustainable development goals as a network of targets. **Sustainable development**, 23(3), 176-187. |
| LEE, J. H., HANCOCK, M. G., & HU, M.-C., 2014 | Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. **Technological Forecasting and Social Change**, 89, 80-99. |
| LEE, K.-H., & MIN, B., 2015 | Green R&D for eco-innovation and its impact on carbon emissions and firm performance. **Journal of cleaner production**, 108, 534-542. |
| LEE, S. Y., FLORIDA, R., & ACS, Z., 2004 | Creativity and entrepreneurship: A regional analysis of new firm formation. **Regional Studies**, 38(8), 879-891. |
| LEE, S. Y., FLORIDA, R., & GATES, G., 2010 | Innovation, human capital, and creativity. **International Review of Public Administration**, 14(3), 13-24. |
| LEE, Y. C., CHU, P. Y., & TSENG, H. L., 2011 | Corporate performance of ICT-enabled business process re-engineering. **Industrial Management & Data Systems.** |
| LEE, Y.-J., & HUANG, C.-M., 2007 | Sustainability index for Taipei. **Environmental Impact Assessment Review**, 27(6), 505-521. |
| LELE, S., 1998 | Resilience, sustainability, and environmentalism. **Environment and Development Economics**, 3(2), 249-254. |
| LÉLÉ, S. M., 1991 | Sustainable development: a critical review. **World Development**, 19(6), 607-621. |
| LEORKE, D., WYATT, D., & MCQUIRE, S., 2018 | More than just a library": Public libraries in the 'smart city. **City, culture and society**, 15, 37-44. |

| | |
|---|---|
| LETAIFA, S. B., 2015 | How to strategize smart cities: Revealing the SMART model. **Journal of Business Research**, 68(7), 1414-1419. |
| LEVALLOIS, C., 2010 | Can de-growth be considered a policy option? A historical note on Nicholas Georgescu-Roegen and the Club of Rome. **Ecological economics**, 69(11), 2271-2278. |
| LEVANTIS, T., & GANI, A., 2000 | Tourism demand and the nuisance of crime. **International Journal of Social Economics.** |
| LEWIS, M., 2006 | **Governance and corruption in public health care systems**. Center for Global Development working paper (78). |
| LEWIS, W. A., 1954 | Economic development with unlimited supplies of labour. |
| LEYDEN, K. M., 2003 | Social capital and the built environment: the importance of walkable neighborhoods. **American journal of public health**, 93(9), 1546-1551. |
| LI, L., & BUHALIS, D., 2005 | Predicting internet usage for travel bookings in China. **Information and communication technologies in tourism** 2005 (pp. 429-439). Springer. |
| LI, L., TAEIHAGH, A., & TAN, S. Y., 2022 | What factors drive policy transfer in smart city development? Insights from a Delphi study. **Sustainable cities and society**, 84, 104008. |
| LI, W., 2018 | Internet and entrepreneurship-an empirical study based on Beijing youth entrepreneurship data. **Economics and Management Research**, 39(5), 114-129. |
| LI, W., & YI, P., 2020 | Assessment of city sustainability—Coupling coordinated development among economy, society and environment. **Journal of cleaner production**, 256, 120453. |
| LI, X., X. LI, J. WOETZEL, G. ZHANG, AND Y. ZHANG., 2014 | **The China urban sustainability index 2013.** The urban China initiative. M. G. I. A. T. U. C. Initiative. Http://www.urbanchinainitiative.org/ |
| LI, Y., LIN, Y., & GEERTMAN, S. C. M., 2015 | **The development of smart cities in China.** The development of smart cities in China. In Proc. of the 14th International Conference on Computers in Urban Planning and Urban Management (pp. 7-10). |
| LIAO, S., CHEN, X., QIAN, Y., & SHEN, L., 2017 | **Comparative analysis of the indicator system for guiding smart city development.** Proceedings of the 20th international symposium on advancement of construction management and real estate. |
| LIM, C., & LIU, E., 2010 | **Smart cities and eco-warriors.** Routledge. |
| LIM, S. B., MALEK, J. A., YUSSOFF, M. F. Y. M., & YIGITCANLAR, T., 2021 | Understanding and acceptance of smart city policies: Practitioners' perspectives on the Malaysian smart city framework. **Sustainability**, 13(17), 9559. |

| | |
|---|---|
| LIN, X., REN, T., WU, H., & XIAO, Y., 2021 | Housing price, talent movement, and innovation output: Evidence from Chinese cities. **Review of Development Economics**, 25(1), 76-103. |
| LIND, E. A., & TYLER, T. R., 1988 | **The social psychology of procedural justice**. Springer Science & Business Media. |
| LITTIG, B., & GRIESSLER, E., 2005 | Social sustainability: a catchword between political pragmatism and social theory. **International journal of sustainable development**, 8(1-2), 65-79. |
| LIU, Z., ZHANG, H., ZHANG, Y.-J., & ZHU, T.-T., 2020 | How does industrial policy affect the eco-efficiency of industrial sector? Evidence from China. **Applied Energy**, 272, 115206. |
| LJAJIĆ, S., STOŠKOVIĆ, M., & NOVAKOVIĆ, I., 2018 | Paradigm of sustainability in the concept of human development. **Škola biznisa**(2), 83-97. |
| LOEWE, M., & RIPPIN, N., 2015 | **Translating an ambitious vision into global transformation: the 2030 agenda for sustainable development.** Discussion Paper. |
| LOMBARDI, P., GIORDANO, S., FAROUH, H., & YOUSEF, W., 2012 | Modelling the smart city performance. Innovation: **The European Journal of Social Science Research**, 25(2), 137-149. |
| LOMBORG, B., 2004 | **Global crises, global solutions.** Cambridge university press. |
| LOVE, I., & ZICCHINO, L., 2006 | Financial development and dynamic investment behavior: Evidence from panel VAR. **The Quarterly Review of Economics and Finance**, 46(2), 190-210. |
| LU, B., TAN, X., & ZHANG, J., 2019 | The crowding out effect of booming real estate markets on corporate TFP: evidence from China. **Accounting & Finance**, 58(5), 1319-1345. |
| LUCAS JR, R. E., 1988 | On the mechanics of economic development. **Journal of monetary economics**, 22(1), 3-42. |
| LUCIDI, F., 2008 | **Labour market flexibility and productivity growth: new evidence from firm-level data**. Xxiii national conference of labour economics, Brescia. |
| LUNA-REYES, L. F., GIL-GARCIA, J. R., & CRUZ, C. B., 2007 | Collaborative digital government in Mexico: Some lessons from federal Web-based interorganizational information integration initiatives. **Government information quarterly**, 24(4), 808-826. |
| MA, R., & LAM, P. T., 2019 | Investigating the barriers faced by stakeholders in open data development: A study on Hong Kong as a "smart city". **Cities**, 92, 36-46. |
| MACCANI, G., DONNELLAN, B., & HELFERT, M., 2013 | **A comprehensive framework for smart cities.** 2nd International Conference on Smart Grids and Green IT Systems. |

MACINTOSH, A., 2004 **Characterizing e-participation in policy-making.** 37th annual Hawaii international conference on system sciences, 2004.

MACKE, J., CASAGRANDE, R. M., SARATE, J. A. R., & SILVA, K. A., 2018 Smart city and quality of life: Citizens' perception in a Brazilian case study. **Journal of cleaner production**, 182, 717-726.

MÄDING, H., 2001 And the winner is… Standpunkt: Städte-Rankings. **Difu-Berichte**, 2(2001), 2-3.

MAGIS, K., & SHINN, C., 2009 **Emergent themes of social sustainability Understanding the Social Aspect of Sustainability**, New York: Routledge.

MAHALIK, M. K., MALLICK, H., & PADHAN, H., 2021 Do educational levels influence the environmental quality? The role of renewable and non-renewable energy demand in selected BRICS countries with a new policy perspective. **Renewable Energy**, 164, 419-432.

MAHMOOD, I. P., & RUFIN, C., 2005 Government's dilemma: The role of government in imitation and innovation. **Academy of management review**, 30(2), 338-360.

MAJI, S. K., & LAHA, A., 2021 The role of digital skill in mitigating digital divide: evidences from Asia-Pacific region. **Rajagiri Management Journal.**

MALENA, C., & MCNEIL, M., 2010 **Social accountability in Africa: An introduction. Demanding good governance: Lessons from social accountability initiatives in Africa**. The World Bank1-28.

MANHART, A., 2011 International Cooperation for Metal Recycling From Waste Electrical and Electronic Equipment: An Assessment of the "Best-of-Two-Worlds" Approach. **Journal of industrial ecology**, 15(1), 13-30.

MANITIU, D. N., & PEDRINI, G., 2016 Urban smartness and sustainability in Europe. An ex ante assessment of environmental, social and cultural domains. **European planning studies**, 24(10), 1766-1787.

MANKIW, N. G., ROMER, D., & WEIL, D. N., 1992 A contribution to the empirics of economic growth. **The Quarterly Journal of Economics**, 107(2), 407-437.

MANNING, A., 1972 Blueprint for survival. **Nature**, 235(5334), 179-179.

MANSFIELD, E., 1980 Basic research and productivity increase in manufacturing. **The American Economic Review**, 70(5), 863-873.

MANTLANA, K. B., & MAOELA, M. A., 2020 Mapping the interlinkages between sustainable development goal 9 and other sustainable development goals: A preliminary exploration. **Business Strategy & Development**, 3(3), 344-355.

MANVILLE, C., COCHRANE, G., CAVE, J., MILLARD, J., PEDERSON, J. K., THAARUP, R. K., LIEBE, A., WISSNER, M., MASSINK, R., & KOTTERINK, B., 2014 **Mapping smart cities in the EU.** EPRS.

MARCH, H., & RIBERA-FUMAZ, R., 2016 Smart contradictions: The politics of making Barcelona a Self-sufficient city. **European Urban and Regional Studies**, 23(4), 816-830.

MARIN, C., DOROBANTU, R., CODREANU, D., & MIHAELA, R., 2012 The fruit of collaboration between local government and private partners in the sustainable development community case study: County Valcea. **Economy Transdisciplinarity Cognition**, 15(2), 93.

MARSAL-LLACUNA, M.-L., COLOMER-LLINÀS, J., & MELÉNDEZ-FRIGOLA, J., 2015 Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. **Technological Forecasting and Social Change**, 90, 611-622.

MARSH, R. M., 2014 Modernization theory, then and now. **Comparative Sociology**, 13(3), 261-283.

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.

MARTINS, J., & VEIGA, L., 2018 **Innovations in digital government as business facilitators: implications for Portugal.** Gabinete de Estratégia e Estudos: GEE (Office for Strategy and Studies)(97), 1-35.

MASIK, G., SAGAN, I., & SCOTT, J. W., 2021 Smart City strategies and new urban development policies in the Polish context. **Cities**, 108, 102970.

MASKUS, K. E., & MCDANIEL, C., 1999 Impacts of the Japanese patent system on productivity growth. **Japan and the World Economy**, 11(4), 557-574.

MATZNER, E., SCHETTKAT, R., & WAGNER, M., 1990 Labour market effects of new technology. B, 22(7), 687-709.

MAYFIELD, D. L., 2016 Medical patents and how new instruments or medications might be patented. **Missouri medicine**, 113(6), 456.

MCCOLLUM, D. L., ECHEVERRI, L. G., BUSCH, S., PACHAURI, S., PARKINSON, S., ROGELJ, J., KREY, V., Connecting the sustainable development goals by their energy inter-linkages. **Environmental Research Letters**, 13(3), 033006.

MINX, J. C., NILSSON, M., & STEVANCE, A.-S., 2018

MCCORMICK, J., 1995 **The Global Environmental Movement**, Second Edition. John Wiley & Sons, New York.

MCGOWAN, M. A., & ANDREWS, D., 2017 **Skills mismatch, productivity and policies: Evidence from the second wave of PIAAC.** OECD.

MCMANUS, J., & MULLETT, D., 2001 **Better Health, Lower Crime: A briefing for the NHS and partner agencies.** Nacro London.

MCMANUS, P., 1998 SUSTAINABILITY, PLANNING AND URBAN FORM: The approaches of Troy, Newman & Kenworthy, Trainer and Rees. **Australian planner**, 35(3), 162-168.

MCNEILL, D., 2016 **Global cities and urban theory.** Sage.

MEADOWS, D. H., 1998 **Indicators and information systems for sustainable development.** The Sustainability Institute.

MEADOWS, D. H., MEADOWS, D. H., RANDERS, J., & BEHRENS III, W. W., 1972 **The limits to growth: a report to the club of Rome**, 91.

MEEGAN, R., & MITCHELL, A., 2001 'It's not community round here, it's neighbourhood': neighbourhood change and cohesion in urban regeneration policies. **Urban studies**, 38(12), 2167-2194.

MEGA, V. P., & PEDERSEN, J., 1998 **Urban sustainability indicators**. EUROPEAN FOUNDATION for the Improvement of Living and Working Conditions.

MEGHISAN-TOMA, G.-M., & CLODNITCHI, A. R., 2018 Research on EU-28 use of ICT for cultural purpose. **Economic computation and economic cybernetics studies and research**, 52(3), 161-169.

MEH, C. A., 2005 Entrepreneurship, wealth inequality, and taxation. **Review of Economic Dynamics**, 8(3), 688-719.

MEIJER, A., & BOLÍVAR, M. P. R., 2016 Governing the smart city: a review of the literature on smart urban governance. **Revue Internationale des Sciences Administrative**s, 82(2), 417-435.

MENDONÇA, M., MOREIRA, B., COELHO, J., CACHO, N., LOPES, F., CAVALCANTE, E., DIAS, A., RIBEIRO, J. L., LOIOLA, E., & ESTAREGUE, D., 2016 **Improving public safety at fingertips: a smart city experience.** 2016 IEEE international smart cities conference (isc2).

MENSAH, J., 2019 Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. **Cogent Social Sciences**, 5(1), 1653531.

MHANGARA, P., MUDAU, N., MBOUP, G., & MWANIKI, D., 2017 Transforming the City of Cape Town from an Apartheid City to an inclusive smart city. **Smart Economy in Smart Cities** (pp. 951-983). Springer.

MICHIE, J., & SHEEHAN, M., 2003 Labour market deregulation,'flexibility'and innovation. **Cambridge Journal of Economics**, 27(1), 123-143.

MICHL, T. R., 2000 Notes on the New Endogenous Growth Theory A Review of Philippe Aghion and Peter Howitt, Endogenous Growth Theory (Cambridge, MA, 1998: The MIT Press). Metroeconomica, 51(2), 182-190. https://doi.org/10.1111/1467-999x.00087

MICK, C., & CHARLES, P., 1992 Towards an ecological economics of sustainability. **Ecological economics**, 6(1), 7-34. https://doi.org/https://doi.org/10.1016/0921-8009(92)90036-R

MIHAJLO, M., & EDUARD, P., 1974 **Mankind at the Turning Point-The Second Report to the Club of Rome**. New York, EP Dutton.

MILGROM, P., & ROBERTS, J., 1995 Complementarities and fit strategy, structure, and organizational change in manufacturing. **Journal of accounting and economics**, 19(2-3), 179-208.

MILLS, J. E., & LAW, R., 2004 **Handbook of consumer behavior, tourism, and the Internet.** Psychology Press.

MIREMADI, I., SABOOHI, Y., & ARASTI, M., 2019 The influence of public R&D and knowledge spillovers on the development of renewable energy sources: The case of the Nordic countries. **Technological Forecasting and Social Change**, 146, 450-463.

MISHAN, E. J., 1967 **Pareto optimality and the law**. Oxford economic papers, 19(3), 255-287.

MISRA, V., & PANDEY, S., 2005 Hazardous waste, impact on health and environment for development of better waste management strategies in future in India. **Environment international**, 31(3), 417-431.

MITCHAM, C., 1995 The concept of sustainable development: its origins and ambivalence. **Technology in Society**, 17(3), 311-326.

MITCHELL, G., 1996 Problems and fundamentals of sustainable development indicators. **Sustainable development**, 4(1), 1-11.

MOCAN, H. N., 1999 Structural unemployment, cyclical unemployment, and income inequality. **Review of Economics and Statistics**, 81(1), 122-134.

MOHAN, A., DUBEY, G., AHMED, F., & SIDHU, A., 2017 **Smart cities index: a tool for evaluating cities.** Indian School of Business: Hyderabad, India.

MOHAN, R., 2007 Determinants of ICT expenditure using logit transformation for proportion data analysis. **Journal of Information Technology Impact**, 7(2), 145-158.

MOHANTY, S. P., CHOPPALI, U., & KOUGIANOS, E., 2016 Everything you wanted to know about smart cities: The Internet of things is the backbone. **IEEE Consumer Electronics Magazine**, 5(3), 60-70.

MOLLICK, E. R., & KUPPUSWAMY, V., 2014 **After the campaign: Outcomes of crowdfunding.** UNC Kenan-Flagler Research Paper(2376997).

MONFAREDZADEH, T., & BERARDI, U., 2015 Beneath the smart city: Dichotomy between sustainability and competitiveness. **International Journal of Sustainable Building Technology and Urban Development,** 6(3), 140-156.

MONZON, A., 2015 **Smart cities concept and challenges: bases for the assessment of smart city projects.** 2015 international conference on smart cities and green ICT systems (smartgreens).

MOOIJ, J., 2003 Smart governance. **Politics in the policy process in Andhra Pradesh**, India, 22-23.

MOORE, F., 2009 Climate change and air pollution: exploring the synergies and potential for mitigation in industrializing countries. **Sustainability**.

MORETTI, E., 2004 **Human capital externalities in cities.** In Handbook of regional and urban economics (Vol. 4, pp. 2243-2291). Elsevier.

MORRIS, D., 2000 Direct democracy and the Internet. **Loy. LAL Review**, 34, 1033.

MORSE, S. W., 2009 **Smart communities: How citizens and local leaders can use strategic thinking to build a brighter future.** John Wiley & Sons.

MOSANNENZADEH, F., & VETTORATO, D., 2014 Defining smart city. A conceptual framework based on keyword analysis. **TeMA-Journal of Land Use, Mobility and Environment.**

MOSS KANTER, R., & LITOW, S. S., 2009 I**nformed and interconnected: A manifesto for smarter cities. Harvard** Business School General Management Unit Working Paper(09-141).

MOSTAFA, R. H., WHEELER, C., & JONES, M. V., 2005 Entrepreneurial orientation, commitment to the Internet and export performance in small and medium sized exporting firms. **Journal of international Entrepreneurship**, 3(4), 291-302.

MULLIGAN, L., 2010 **Smart cities and sustainable technology**. Siemens Ltd.

MUMTAZ, M., 2021 Role of civil society organizations for promoting green and blue infrastructure to adapting climate change: Evidence from Islamabad city, Pakistan. **Journal of cleaner production**, 309, 127296.

MUNDA, G., 1997 Environmental economics, ecological economics, and the concept of sustainable development. **Environmental values**, 6(2), 213-233.

MUNIER, N., ZIARA, M. M., COLE, R., CURIEL, J., ESTEBAN, A., ERTSEN, M., LALL, V., LALL, S., LITMAN, T., & MORRISON, R., 2007 **Handbook on urban sustainability.** Springer.

MURCOTT, S., 1997 **Definitions of sustainable development.** AAAS annual conference, IIASA sustainability indicators symposium.

MURGANTE, B., & BORRUSO, G., 2015 Smart cities in a smart world. **Future city architecture for optimal living** (pp. 13-35). Springer.

MURPHY, R. H., & O'REILLY, C., 2019 Applying panel vector autoregression to institutions, human capital, and output. **Empirical Economics**, 57(5), 1633-1652.

MYEONG, S., JUNG, Y., & LEE, E., 2018 A study on determinant factors in smart city development: An analytic hierarchy process analysis. **Sustainability**, 10(8), 2606.

NAGERI, K. I., & GUNU, U., 2020 Corruption and Ease of Doing Business: Evidence from ECOWAS. Acta Universitatis Sapientiae, **Economics and Business**, 8(1), 19-37.

NAHUIS, R., & DE GROOT, H., 2003 **Rising Skills Premia. You ain't seen nothing yet.** Discussion Paper Series/Tjalling C. Koopmans Research Institute, 3(02).

NAIR, M., PRADHAN, R. P., & ARVIN, M. B., 2020 Endogenous dynamics between R&D, ICT and economic growth: Empirical evidence from the OECD countries. **Technology in Society**, 62, 101315.

NAM, T., & PARDO, T. A., 2011 **Conceptualizing smart city with dimensions of technology, people, and institutions.** Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times.

NAMBISAN, S., 2013 Industry technical committees, technological distance, and innovation performance. **Research Policy**, 42(4), 928-940.

United Nations, 2000 **United Nations millennium declaration**. New York: united nations. In: a/res/55/2.

United Nations, 1972 **Development and environment.** Report and working papers of a panel of experts convened by the secretary-general of the united nations conference on the human environment.

United Nations, 2003 **UN global e-government survey 2003.** Department of Economic and Social Affairs New York.

United Nations, 2014 **World urbanization prospects:** The 2014 revision, highlights. department of economic and social affairs. Population Division, United Nations, 32.

NEAL, S., BENNETT, K., JONES, H., COCHRANE, A., & MOHAN, G., 2015 Multiculture and public parks: Researching super-diversity and attachment in public green space. **Population, space and place**, 21(5), 463-475.

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.

NELSON, P., BAGLINO, A., HARRINGTON, W., SAFIROVA, E., & LIPMAN, A., 2007 Transit in Washington, DC: Current benefits and optimal level of provision. **Journal of urban economics**, 62(2), 231-251.

NEUMAN, M., 2005 The compact city fallacy. **Journal of planning education and research**, 25(1), 11-26.

NEUMAYER, E., 2003 **Weak versus strong sustainability: exploring the limits of two opposing paradigms.** Edward Elgar Publishing.

NEWMAN, M., 2010 **Networks: An Introduction.** Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199206650.001.0001

NEWMAN, P., & JENNINGS, I., 2012 **Cities as sustainable ecosystems: principles and practices.** Island press.

NFUKA, E. N., & RUSU, L., 2010 **Critical success factors for effective IT governance in the public sector organizations in a developing country: The case of Tanzania.** ECIS 2010 Proceedings, 128.

NICOLAS, C., KIM, J., & CHI, S., 2020 Quantifying the dynamic effects of smart city development enablers using structural equation modeling. **Sustainable cities and society**, 53, 101916.

NIE, N. H., JUNN, J., & STEHLIK-BARRY, K., 1996 **Education and democratic citizenship in America.** University of Chicago Press.

NIESTROY, I., 2016 **How are we getting ready? The 2030 Agenda for Sustainable Development in the EU and its Member States: analysis and action so far.** Discussion Paper.

NILSSON, M., GRIGGS, D., & VISBECK, M., 2016 Policy: map the interactions between Sustainable Development Goals. **Nature**, 534(7607), 320-322.

NISSAN, E., MARTIN, M.-Á. G., & PICAZO, M.-T. M., 2011 Relationship between organizations, institutions, entrepreneurship and economic growth process. International **Entrepreneurship and Management Journal**, 7(3), 311-324.

NKETIAH-AMPONSAH, E., & SARPONG, B., 2020 Ease of doing business and foreign direct investment: case of Sub-Saharan Africa. **International Advances in Economic Research**, 26(3), 209-223.

NOH, Y.-H., & YOO, K., 2008 Internet, inequality and growth. **Journal of Policy Modeling**, 30(6), 1005-1016.

| | |
|---|---|
| NOORI, N., HOPPE, T., & DE JONG, M., 2020 | Classifying pathways for smart city development: comparing design, governance and implementation in Amsterdam, Barcelona, Dubai, and Abu Dhabi. **Sustainability**, 12(10), 4030. |
| NORRIS, D. T., & CONCEIÇÃO, S., 2004 | Narrowing the digital divide in low-income, urban communities. **New directions for adult and continuing education**, (101), 69-81. |
| NORTH, D. C., 1990 | A transaction cost theory of politics. **Journal of theoretical politics**, 2(4), 355-367. |
| NORTHRUP, T. A., & THORSON, S. J., 2003 | **The web of governance and democratic accountability.** 36th annual Hawaii international conference on system sciences. |
| NURMI, R., 1998 | Knowledge-intensive firms. **Business Horizons**, 41(3), 26-33. |
| O'NEILL, D. W., FANNING, A. L., LAMB, W. F., & STEINBERGER, J. K., 2018 | A good life for all within planetary boundaries. **Nature** sustainability, 1(2), 88-95. |
| ODENDAAL, N., 2003 | Information and communication technology and local governance: Understanding the difference between cities in developed and emerging economies. **Computers, environment and urban systems**, 27(6), 585-607. |
| OECD, 2010 | Improving health sector efficiency: the role of information and communication technologies. |
| OESCH, D., 2009 | C. Alexander: Market Risk Analysis (four-volume set). **Financial Markets and Portfolio Management**, 23(3), 331-332. https://doi.org/10.1007/s11408-009-0108-z |
| OH, C.-O., 2005 | The contribution of tourism development to economic growth in the Korean economy. **Tourism Management**, 26(1), 39-44. |
| OLSON, M., SARNA, N., & SWAMY, A. V., 2000 | Governance and growth: A simple hypothesis explaining cross-country differences in productivity growth. **Public choice**, 102(3), 341-364. |
| ORLOWSKI, C., 2021 | Project management methods for open data projects in Smart Cities. **Management of IOT Open Data Projects in Smart Cities** (pp. 127-154): Elsevier. |
| ORTEGA ALVAREZ, D., 2002 | **Crime and entrepreneurship.** Venezuela: Office of Economic and Financial Advisors to the National Assembly. |
| OSBORN, D., & BIGG, T., 1998 | **Earth Summit II**, outcomes and analyses Earthscan. In: London. |

| | |
|---|---|
| OXOBY, R., 2009 | Understanding social inclusion, social cohesion, and social capital. **International Journal of Social Economics.** |
| OYERINDE, Y., & BANKOLE, F., 2019 | **Investigating the efficiency of ICT infrastructure utilization: a data envelopment analysis approach**. International conference on social implications of computers in developing countries. |
| PACKARD, M. D., & BYLUND, P. L., 2018 | On the relationship between inequality and entrepreneurship. **Strategic Entrepreneurship Journal**, 12(1), 3-22. |
| PALMAR, I., & NASCIMENTO, O., 2002 | Health action theatre by seniors: Community development and education with groups of diverse languages and cultures. Generations: **Journal of the American Society on Aging**, 26(3), 65-67. |
| PAN, W., GHOSHAL, G., KRUMME, C., CEBRIAN, M., & PENTLAND, A., 2013 | Urban characteristics attributable to density-driven tie formation. **Nature communications,** 4(1), 1-7. |
| PAPPA, E., KONTODIMOPOULOS, N., PAPADOPOULOS, A. A., & NIAKAS, D., 2009 | Assessing the socio-economic and demographic impact on health-related quality of life: evidence from Greece. **International journal of public health**, 54(4), 241-249. |
| PARDO, T. A., NAM, T., & BURKE, G. B., 2012 | E-government interoperability: Interaction of policy, management, and technology dimensions. **Social science computer review**, 30(1), 7-23. |
| PARK, H. M., & PERRY, J. L., 2008 | Do campaign web sites really matter in electoral civic engagement? Empirical evidence from the 2004 post-election internet tracking survey. **Social science computer review**, 26(2), 190-212. |
| PARKIN, S., SOMMER, F., & UREN, S., 2003 | **Sustainable development: understanding the concept and practical challenge.** Proceedings of the institution of civil engineers-engineering sustainability. |
| PASKALEVA, K. A., 2009 | Enabling the smart city: The progress of city e-governance in Europe. **International Journal of Innovation and regional development,** 1(4), 405-422. |
| PATHAK, R. D., SINGH, G., BELWAL, R., & SMITH, R., 2007 | E-governance and Corruption-developments and Issues in Ethiopia. **Public Organization Review**, 7(3), 195-208. |
| PATRÃO, C., MOURA, P., & ALMEIDA, A. T. D., 2020 | Review of smart city assessment tools. **Smart Cities**, 3(4), 1117-1132. |
| PATRICK, K., GRISWOLD, W. G., RAAB, F., & INTILLE, S. S., 2008 | Health and the mobile phone. **American journal of preventive medicine**, 35(2), 177-181. |

PAYNE, R. A., 1995 — Freedom and the environment. J**ournal of democracy**, 6(3), 41-55.

PEARCE, D., 2002 — An intellectual history of environmental economics. **Annual review of energy and the environment**, 27(1), 57-81.

PEARCE, D., & ATKINSON, G., 1998 — The concept of sustainable development: An evaluation of its usefulness ten years after Brundtland. **Revue Suisse d Economie Politique et de Statistique**, 134, 251-270.

PEARCE, D., & BARBIER, E., 1989 — **Blueprint for a sustainable economy**. Routledge.

PEARCE, D., & REDCLIFT, M., 1988 — Sustainable Development: Special Issue. **Futures**, 20(60), 47-56.

PEARCE, D. W., TURNER, R. K., & TURNER, R. K., 1990 — **Economics of natural resources and the environment.** Johns Hopkins University Press.

PEET, R., 2000 — Culture, imaginary, and rationality in regional economic evelopment. **Environment and Planning**A, 32(7), 1215-1234.

PEET, R., & HARTWICK, E. R., 1999 — **Theories of Development.** New York. In: Guilford Press.

PELLETIER, J., & BRENT, J. M., 2002 — Parent participation in children'school readiness: The effects of parental self-efficacy, cultural diversity and teacher strategies. **International Journal of Early Childhood**, 34(1), 45-60.

PEREIRA, G. V., MACADAR, M. A., LUCIANO, E. M., & TESTA, M. G., 2017 — Delivering public value through open government data initiatives in a Smart City context. **Information Systems Frontiers,** 19(2), 213-229.

PEREIRA, G. V., PARYCEK, P., FALCO, E., & KLEINHANS, R., 2018 — Smart governance in the context of smart cities: A literature review. **Information Polity**, 23(2), 143-162.

PERERA, C., ZASLAVSKY, A., CHRISTEN, P., & GEORGAKOPOULOS, D., 2014 — Sensing as a service model for smart cities supported by internet of things. **Transactions on Emerging Telecommunications Technologies**, 25(1), 81-93.

PERRIN, A., & DUGGAN, M., 2015 — Americans' internet access: 2000-2015.

PERSYN, D., & WESTERLUND, J., 2008 — Error-correction–based cointegration tests for panel data. ***The STATA journal***, *8*(2), 232-241.

PERVEEN, S., KAMRUZZAMAN, M., & YIGITCANLAR, T., 2019 What to assess to model the transport impacts of urban growth? A Delphi approach to examine the space–time suitability of transport indicators. **International Journal of Sustainable Transportation**, 13(8), 597-613.

PESARAN, M. H., 2004 **General diagnostic tests for cross section dependence in panels**. CESifo Working Paper, No. 1229, Center for Economic Studies and ifo Institute (CESifo), Munich.

PEŠIĆ, I., & KOJIĆ, R., 2012 THE ROLE OF ICT IN MONITORING AND SOLVING TRAFFIC ISSUES. **Innovative Issues and Approaches**.

PETERS, B., 2004 **Employment effects of different innovation activities: Microeconometric evidence.** ZEW-Centre for European Economic Research Discussion Paper(04-073).

PETROLO, R., LOSCRI, V., & MITTON, N., 2017 Towards a smart city based on cloud of things, a survey on the smart city vision and paradigms. **Transactions on Emerging Telecommunications Technologies**, 28(1), e2931.

PETROVA-ANTONOVA, D., & ILIEVA, S., 2018 **Smart cities evaluation–a survey of performance and sustainability indicators.** 2018 44th euromicro conference on software engineering and advanced applications (seaa).

PHILLIS, Y. A., KOUIKOGLOU, V. S., & VERDUGO, C., 2017 Urban sustainability assessment and ranking of cities. **Computers, environment and urban systems**, 64, 254-265.

PIGOU, A. C., 1932 The effect of reparations on the ratio of international interchange. **The economic journal**, 42(168), 532-543.

PIKETTY, T., 2014 **Capital in the twenty-first century. In Capital in the twenty-first century.** Harvard University Press.

PINES, A. M., LERNER, M., & SCHWARTZ, D., 2010 Gender differences in entrepreneurship: equality, diversity and inclusion in times of global crisis. **Equality, diversity and inclusion: An International journal.**

PISSARIDES, C. A., 2000 **Equilibrium unemployment theory.** MIT press.

PIZZOL, M., SCOTTI, M., & THOMSEN, M., 2013 Network Analysis as a tool for assessing environmental sustainability: Applying the ecosystem perspective to a Danish Water Management System. **Journal of environmental management**, 118, 21-31.

PLAMBECH, T., & VAN DEN BOSCH, C. C. K., 2015 The impact of nature on creativity–A study among Danish creative professionals. **Urban Forestry & Urban Greening**, 14(2), 255-263.

PLATJE, J., 2008 An institutional capital approach to sustainable development. **Management of Environmental Quality: An International Journal**.

PLUNKETT, D., 1990 The creative organization: An empirical investigation of the importance of participation in decision-making. **The Journal of Creative Behavior.**

POLICY, E. U. E. C. D.-G. F. R., 2011 **Cities of tomorrow: Challenges, visions, ways forward.** Publications Office of the European Union.

POLZIN, F., MIGENDT, M., TÄUBE, F. A., & VON FLOTOW, P., 2015 Public policy influence on renewable energy investments—A panel data study across OECD countries. **Energy Policy**, 80, 98-111.

POPE III, C. A., BURNETT, R. T., THUN, M. J., CALLE, E. E., KREWSKI, D., ITO, K., & THURSTON, G. D., 2002 Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. **Jama**, 287(9), 1132-1141.

PORTER, M. E., 1997 New strategies for inner-city economic development. **Economic development quarterly**, 11(1), 11-27.

POZDNIAKOVA, A. M., 2017 Smart sustainable cities: the concept and approaches to measurement. **Acta Innovations**(22), 5-19.

PRADHAN, P., COSTA, L., RYBSKI, D., LUCHT, W., & KROPP, J. P., 2017 A systematic study of sustainable development goal (SDG) interactions. **Earth's Future**, 5(11), 1169-1179.

PRADHAN, R. P., ARVIN, M. B., NAIR, M. S., HALL, J. H., & BENNETT, S. E., 2021 Sustainable economic development in India: The dynamics between financial inclusion, ICT development, and economic growth. **Technological Forecasting and Social Change**, 169, 120758.

PRAHARAJ, S., HAN, J. H., & HAWKEN, S., 2018 Urban innovation through policy integration: Critical perspectives from 100 smart cities mission in India. **City, culture and society**, 12, 35-43.

PRIANO, F. H., & GUERRA, C. F., 2014 **A framework for measuring smart cities.** Proceedings of the 15th annual international conference on digital government research.

PRIDEAUX, B., 2000 The role of the transport system in destination development. **Tourism Management**, 21(1), 53-63.

PROOPS, J. L., 1989 Ecological economics: rationale and problem areas. **Ecological economics**, 1(1), 59-76.

PSHISVA, R., & SUAREZ, G. A., 2006 **'Captive markets': the impact of kidnappings on corporate investment in Colombia.** Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board, Washington, D.C.

PUGA, D., 2002 European regional policies in light of recent location theories. **Journal of economic geography**, 2(4), 373-406.

PUTNAM, R., 1993 — The prosperous community: Social capital and public life. **The American prospect**, 13(Spring), Vol. 4. Available online: http://www. prospect. org/print/vol/13 (accessed 7 April 2022).

PUTNAM, R. D., 2000 — Bowling alone: America's declining social capital. **Culture and politics** (pp. 223-234). Springer.

RABARI, C., & STORPER, M., 2015 — The digital skin of cities: urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data. **Cambridge Journal of Regions, Economy and Society**, 8(1), 27-42.

RAGNEDDA, M., RUIU, M. L., & ADDEO, F., 2022 — The self-reinforcing effect of digital and social exclusion: The inequality loop. **Telematics and Informatics**, 101852.

RAJKUMAR, A. S., & SWAROOP, V., 2008 — Public spending and outcomes: Does governance matter? **Journal of development economics**, 86(1), 96-111.

RALCHEV, P., 2004 — The role of civil society in fighting corruption and organized crime in Southeast Europe. **Southeast European and Black Sea Studies**, 4(2), 325-331.

RALLET, A., & ROCHELANDET, F., 2007 — **ICTs and inequalities: The digital divide, in Internet and digital economics: Principles, methods and applications,** 693. Cambridge.

RASKIN, P., HANSEN, E., & MARGOLIS, R. M., 1995 — **Water and sustainability: A global outlook.** Stockholm Environment Institute.

RATNER, B., 2009 — The correlation coefficient: Its values range between+ 1/− 1, or do they? **Journal of targeting, measurement and analysis for marketing**, 17(2), 139-142.

RATTEN, V., 2017 — **Entrepreneurship, innovation and smart cities.** Routledge.

RAWORTH, K., 2012 — **A safe and just space for humanity: can we live within the doughnut?** Oxfam.

REDCLIFT, M., 1984 — 'Urban bias' and rural poverty: A Latin American perspective. **The Journal of Development Studies**, 20(3), 123-138.

REDCLIFT, M., 1996 — **Wasted: counting the costs of global consumption**. Routledge.

REES, M., 1995 — Community structure in sand dune annuals: is seed weight a key quantity? **Journal of Ecology,** 857-863.

REES, W. E., 1995 — Achieving sustainability: reform or transformation? **Journal of planning literature**, 9(4), 343-361.

REIBER, L., & HUANG, G., 2018 — **Comparing study on smart city strategies in berlin and shanghai. Third international conference on economic and business management**. Atlantis press.

| | |
|---|---|
| REMENYI, J., 2004 | What is development. **Key issues in development**, 22-44. |
| RETCHLESS, D. P., & BREWER, C. A., 2016 | Guidance for representing **uncertainty on global temperature change maps. International Journal of Climatology,** 36(3), 1143-1159. |
| REYES, G. E., 2001 | Four main theories of development: modernization, dependency, word-system, and globalization. **Nómadas. Revista Crítica de Ciencias Sociales y Jurídicas**, 4(2), 109-124. |
| RIBEIRO, M. M., CUNHA, M. A., & BARBOSA, A. F., 2018 | **E-participation, social media and digital gap: challenges in the Brazilian context**. Proceedings of the 19th annual international conference on digital government research: governance in the data age. |
| RICHMOND, K., & TRIPLETT, R. E., 2018 | ICT and income inequality: a cross-national perspective. International **Review of Applied Economics**, 32(2), 195-214. |
| RICHTER, C., KRAUS, S., & SYRJÄ, P., 2015 | The Smart City as an opportunity for entrepreneurship. **International Journal of Entrepreneurial Venturing**, 7(3), 211-226. |
| RINALDI, A., & SALERNO, I., 2020 | The tourism gender gap and its potential impact on the development of the emerging countries. **Quality & Quantity**, 54(5), 1465-1477. |
| ROBAINA, M., & MADALENO, M., 2020 | The relationship between emissions reduction and financial performance: Are Portuguese companies in a sustainable development path? **Corporate Social Responsibility and Environmental Management**, 27(3), 1213-1226. |
| ROCKSTRÖM, J., STEFFEN, W., NOONE, K., PERSSON, Å., CHAPIN, F. S., LAMBIN, E. F., LENTON, T. M., SCHEFFER, M., FOLKE, C., & SCHELLNHUBER, H. J., 2009 | A safe operating space for humanity. **Nature**, 461(7263), 472-475. |
| RODRIGUES, M., & FRANCO, M., 2021 | The role of citizens and transformation of energy, water, and waste infrastructure for an intelligent, sustainable environment in cities. **Smart and Sustainable Built Environment.** |
| RODRÍGUEZ-BOLÍVAR, M. P., 2015 | **Transforming city governments for successful smart cities.** Springer. |
| RODRÍGUEZ-POSE, A., & LEE, N., 2020 | Hipsters vs. geeks? Creative workers, STEM and innovation in US cities. **Cities**, 100, 102653. |

ROGERS, P. P., JALAL, K. F., & BOYD, J. A., 2007 **An introduction to sustainable development.** Routledge.

ROMAO, J., KOURTIT, K., NEUTS, B., & NIJKAMP, P., 2018 The smart city as a common place for tourists and residents: A structural analysis of the determinants of urban attractiveness. **Cities**, 78, 67-75.

ROMER, P. M., 1990 Endogenous technological change. **Journal of political Economy**, 98(5, Part 2), S71-S102.

ROMM, J., 2002 The internet and the new energy economy. **Resources, conservation and recycling**, 36(3), 197-210.

RONG, Z., WANG, W., & GONG, Q., 2016 Housing price appreciation, investment opportunity, and firm innovation: Evidence from China. **Journal of Housing Economics**, 33, 34-58.

ROSELAND, M., 2000 Sustainable community development: integrating environmental, economic, and social objectives. **Progress in planning**, 54(2), 73-132.

ROY, M., 2009 Planning for sustainable urbanisation in fast growing cities: Mitigation and adaptation issues addressed in Dhaka, Bangladesh. **Habitat international**, 33(3), 276-286.

RUHLANDT, R. W. S., 2018 The governance of smart cities: A systematic literature review. **Cities**, 81, 1-23.

RUSSO, F., RINDONE, C., & PANUCCIO, P., 2016 European plans for the smart city: from theories and rules to logistics test case. **European planning studies**, 24(9), 1709-1726.

RUTTAN, V. W., 1991 Sustainable growth in agricultural production: Poetry, policy and science. **Sustainability, growth, and poverty alleviation**, 19.

SACKS, A., & LEVI, M., 2010 Measuring government effectiveness and its consequences for social welfare in sub-Saharan African countries. **Social Forces**, 88(5), 2325-2351.

SÆBØ, Ø., ROSE, J., & MOLKA-DANIELSEN, J., 2010 E-Participation: Designing and managing political discussion forums. **Social science computer review**, 28(4), 403-426.

SAEGERT, S., & WINKEL, G., 2004 Crime, social capital, and community participation. **American journal of community psychology**, 34(3), 219-233.

SAGASTI, F., & COLBY, M., 1993 Eco-development and perspectives on global change from developing countries. Global accord: **Environmental challenges and international responses,** 175-203.

SAJJAD, F., NOREEN, U., & ZAMAN, K., 2014 Climate change and air pollution jointly creating nightmare for tourism industry. **Environmental Science and Pollution Research**, 21(21), 12403-12418.

SALA-I-MARTÍN, X., 2016 **The global competitiveness report** 2016–2017, WEF.

SAN CHIA, P., LAW, S. H., TRINUGROHO, I., WIWOHO, J., DAMAYANTI, S. M., & SERGI, B. S., 2022 Dynamic linkages among transparency, income inequality and economic growth in developing countries: Evidence from panel vector autoregressive (PVAR) model. **Research in International Business and Finance**, 60, 101599.

SANDBROOK, R., 1992 Earth Summit, 92: The United Nations Conference on Environment and Development, Rio de Janeiro. Regency Press Corporation Ltd.

SANDERS, N. R., 2007 An empirical study of the impact of e-business technologies on organizational collaboration and performance. **Journal of operations management**, 25(6), 1332-1347.

SANDULESCU, E., 2004 The contribution of waste management to the reduction of greenhouse gas emissions with applications in the city of Bucharest. **Waste Management & Research**, 22(6), 413-426.

SANFORD, C., & ROSE, J., 2007 Characterizing e participation. **International Journal of Information Management**, 27(6), 406-421.

SANG, Z., DING, H., HIGASHI, M., NAKAMURA, J., HARA, M., HASHITANI, T., SUGIURA, J., DI CARLO, C., GIRDINIO, P., & BOLLA, R., 2015 **Key performance indicators definitions for smart sustainable cities**. ITU-T: Geneva, Switzerland.

SAPSFORD, R., TSOURAPAS, G., ABBOTT, P., & TETI, A., 2019 Corruption, trust, inclusion and cohesion in North Africa and the Middle East. **Applied Research in Quality of Life**, 14(1), 1-21.

SARANGI, A. K., & PRADHAN, R. P., 2020 ICT infrastructure and economic growth: A critical assessment and some policy implications. **Decision**, 47(4), 363-383.

SASAKI, H., 2007 **Intellectual property protection for multimedia information technology**. IGI Global.

SCHAEFFER, A., HOLLERT, H., RATTE, H. T., ROß-NICKOLL, M., FILSER, J., MATTHIES, M., OEHLMANN, J., SCHERINGER, M., SCHULZ, R., & SEITZ, A., 2009 An indispensable asset at risk: merits and needs of chemicals-related environmental sciences. **Environmental Science and Pollution Research**, 16(4), 410-413.

SCHAFFERS, H., KOMNINOS, N., PALLOT, M., AGUAS, M., ALMIRALL, E., BAKICI, T., BARROCA, J., CARTER, D., CORRIOU, M., & FERNADEZ, J., 2012 **Smart cities as innovation ecosystems sustained by the future internet.** [Technical Report] 2012, pp.65.

SCHIAVONE, F., APPIO, F. P., MORA, L., & RISITANO, M., 2020 The strategic, organizational, and entrepreneurial evolution of smart cities. **International Entrepreneurship and Management Journa**l, 16(4), 1155-1165.

SCHIAVONE, F., PAOLONE, F., & MANCINI, D., 2019 Business model innovation for urban smartization. **Technological Forecasting and Social Change**, 142, 210-219.

SCHNEIDER, L., GÜNTHER, J., & BRANDENBURG, B., 2010 Innovation and skills from a sectoral perspective: a linked employer–employee analysis. **Economics of Innovation and New Technology**, 19(2), 185-202.

SCHNOLL, H. J., 2015 **E-government: Information, technology, and transformation.** Routledge.

SCHOLTE, J. A., 2004 Civil society and democratically accountable global governance. **Government and opposition**, 39(2), 211-233.

SCHÖNERT, M., 2003 Städteranking und Imagebildung: Die 20 größten Städte in Nachrichten-und Wirtschaftsmagazinen. **BAW Monatsbericht**, 2(03), 1-8.

SCHOOLMAN, E. D., GUEST, J. S., BUSH, K. F., & BELL, A. R., 2012 How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. **Sustainability Science**, 7(1), 67-80.

SCHUMACHER, E., & BEAUTIFUL, S. I., 1973 **If People Mattered.** Harper&Row, New York, NY.

SCHUMPETER, J. A., & NICHOL, A. J., 1934 Robinson's economics of imperfect competition. **Journal of political Economy**, 42(2), 249-259.

SCHÜTZE, F., FÜRST, S., MIELKE, J., STEUDLE, G. A., WOLF, S., & JAEGER, C. C., 2017 The role of sustainable investment in climate policy. **Sustainability**, 9(12), 2221.

SCOONES, I., 2007 Sustainability. **Development in practice**, 17(4-5), 589-596.

SCOPELLITI, M., MOLINARIO, E., BONAIUTO, F., BONNES, M., CICERO, What makes you a 'hero'for nature? Socio-psychological profiling of leaders committed to nature and biodiversity protection across seven EU countries.

| | |
|---|---|
| L., DE DOMINICIS, S., FORNARA, F., ADMIRAAL, J., BERINGER, A., & DEDEURWAERDERE, T., 2018 | **Journal of Environmental Planning and Management**, 61(5-6), 970-993. |
| SEETANAH, B., 2011 | Assessing the dynamic economic impact of tourism for island economies. **Annals of tourism research**, 38(1), 291-308. |
| SEKI, I., 2008 | **The importance of ICT for the knowledge economy: a total factor productivity analysis for selected OECD countries.** International conference on emerging economic issues in a globalizing world, Izmir. |
| SELIGSON, M. A., 2002 | The impact of corruption on regime legitimacy: A comparative study of four Latin American countries. **The journal of Politics**, 64(2), 408-433. |
| SEN, A., 1999 | Development as freedom The globalization and development reader: **Perspectives on development and global change**, 525. |
| SEY, A., & CASTELLS, M., 2004 | 16. From media politics to networked politics: the Internet and the political process. **The network society**, 363. |
| SHANE, S., & VENKATARAMAN, S., 2000 | The promise of entrepreneurship as a field of research. **Academy of management review**, 25(1), 217-226. |
| SHAPIRO, J.M., 2006 | Smart cities: quality of life, productivity, and the growth effects of human capital. **The review of economics and statistics**, 88(2), 324-335. |
| SHARIFI, A., 2019 | A critical review of selected smart city assessment tools and indicator sets. **Journal of cleaner production**, 233, 1269-1283. |
| SHARMA, S. K., & GUPTA, J. N., 2003 | Building blocks of an e-government: A framework. J**ournal of Electronic Commerce in Organizations (JECO)**, 1(4), 34-48. |
| SHEARMAN, R., 1990 | The meaning and ethics of sustainability. **Environmental managemen**t, 14(1), 1-8. |
| SHELTON, T., ZOOK, M., & WIIG, A., 2015 | The 'actually existing smart city'. **Cambridge Journal of Regions, Economy and Society**, 8(1), 13-25. |
| SHI, J., & WANG, W., 2017 | The impact of internet use on entrepreneurial behavior-an empirical study based on microdata. **Journal of Zhejiang University (Humanities and Social Sciences)**, 47(4), 159-175. |
| SHIELDS, K., LANGER, H., WATSON, J., & STELZNER, K., 2009 | **European Green City Index. Assessing the environmental impact of Europe's major cities**. Netherlands. |

| | |
|---|---|
| SHIM, D. C., & EOM, T. H., 2008 | E-government and anti-corruption: Empirical analysis of international data. **Intl Journal of Public Administration**, 31(3), 298-316. |
| SHIRAZI, F., 2008 | The contribution of ICT to freedom and democracy: An empirical analysis of archival data on the Middle East. **The Electronic Journal of Information Systems in Developing Countries**, 35(1), 1-24. |
| SHOSHANI, Y., & BRAUN HAZI, R., 2007 | The use of the Internet environment for enhancing creativity. **Educational Media International**, 44(1), 17-32. |
| SIAU, K., & LONG, Y., 2009 | Factors impacting e-government development. **Journal of Computer Information Systems**, 50(1), 98-107. |
| SILVA, B. N., KHAN, M., & HAN, K., 2018 | Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. **Sustainable cities and society**, 38, 697-713. |
| SIMIONESCU, M., 2021 | The nexus between economic development and pollution in the European Union new member states. The role of renewable energy consumption. **Renewable Energy**, 179, 1767-1780. |
| SIMON, J. L., 1980 | Resources, population, environment: an oversupply of false bad news. **Science**, 208(4451), 1431-1437. |
| SIMONOFSKI, A., ASENSIO, E. S., DE SMEDT, J., & SNOECK, M., 2017 | Citizen participation in smart cities: evaluation framework proposal. 2017 IEEE 19th conference on business informatics (CBI). |
| SINGER, M., 1971 | Beyond tradition and modernity in Madras. **Comparative studies in society and history**, 13(2), 160-195. |
| SMICIKLAS, J., PROKOP, G., STANO, P., & SANG, Z., 2017 | **Collection methodology for key performance indicators for smart sustainable cities.** U4SSC: Geneva, Switzerland. |
| SMILOR, R. W., & WAKELIN, M., 1990 | **Smart infrastructure and economic development: the role of technology and global networks.** The Technopolis Phenomenon, IC2 Institute, University of Texas at Austin, Austin, 100-125. |
| SMITH, B., & STEPHEN, F. H., 1975 | Cost-benefit analysis and compensation criteria: a note. **The economic journal**, 85(340), 902-905. |
| SMITH, D. A., 1997 | Technology, commodity chains and global inequality: South Korea in the 1990s. R**eview of International Political Economy,** 4(4), 734-762. |
| SMITH, S. L., 2012 | Toward inclusive co-management: Factors influencing stakeholder participation. **Coastal Management**, 40(3), 327-337. |

SMITH, T., 1979 — The underdevelopment of development literature: the case of dependency theory. **World Politic**s, 31(2), 247-288.

SMOL, M., KULCZYCKA, J., & AVDIUSHCHENKO, A., 2017 — Circular economy indicators in relation to eco-innovation in European regions. **Clean Technologies and Environmental Policy**, 19(3), 669-678.

SMULDERS, S., 1998 — Technological change, economic growth and sustainability. **Theory and implementation of economic models for sustainable development,** pp. 39-65. Springer.

SMYTH, R., NIELSEN, I., & MISHRA, V., 2009 — 'I've been to Bali too'(and I will be going back): are terrorist shocks to Bali's tourist arrivals permanent or transitory? **Applied Economics**, 41(11), 1367-1378.

SO, A. Y., 1990 — **Social change and development: Modernization, dependency and world-system theories**. Sage.

SÖDERBAUM, P., 1990 — Neoclassical and institutional approaches to environmental economics. **Journal of Economic Issues**, 24(2), 481-492.

SÖDERBAUM, P., 2005 — Environment and Development: An Institutional Version of Ecological Economics. **Dimensions of Environmental and Ecological Economics**, 30.

SÖDERSTRÖM, O., PAASCHE, T., & KLAUSER, F., 2020 — **Smart cities as corporate storytelling. In The Routledge companion to smart cities,** pp. 283-300. Routledge.

SOHAG, K., CHUKAVINA, K., & SAMARGANDI, N., 2021 — Renewable energy and total factor productivity in OECD member countries. **Journal of cleaner production**, 296, 126499.

SOLOW, R. M., 1986 — On the intergenerational allocation of natural resources. **The Scandinavian Journal of Economics**, 141-149.

SOLOW, R. M., 1993 — Policies for economic growth. **Tinbergen lectures on economic policy,** pp. 127-140. Elsevier.

SONE, A., 1988 — An Application of Discrete Choice Analysis to the Modeling of Public Library Use and Choice Behavior. **Library and information science Research**, 10(1), 35-55.

SONG, M., & XIE, Q., 2021 — Evaluation of urban competitiveness of the Huaihe River eco-economic belt based on dynamic factor analysis. **Computational Economics**, 58(3), 615-639.

SPANGENBERG, J. H., 2002 — Environmental space and the prism of sustainability: frameworks for indicators measuring sustainable development. **Ecological indicators**, 2(3), 295-309.

SPETH, J. G., 2003 — Two perspectives on globalization and the environment. **Worlds Apart: Globalization and the Environment,** 1-18.

SRIVASTAVA, S. C., & TEO, T. S., 2010 — E-government, e-business, and national economic performance. **Communications of the association for information systems**, 26(1), 14.

STANLEY, J., & STANLEY, J., 2017 — The importance of transport for social inclusion. **Social Inclusion**, 5(4), 108-115.

STANLEY, T. D., DOUCOULIAGOS, H., & STEEL, P., 2018 — Does ICT generate economic growth? A meta-regression analysis. **Journal of economic surveys**, 32(3), 705-726.

STAVINS, R. N., WAGNER, A. F., & WAGNER, G., 2003 — Interpreting sustainability in economic terms: dynamic efficiency plus intergenerational equity. **Economics Letters**, 79(3), 339-343.

STEVENS, C., 2010 — **Linking sustainable consumption and production: the government role.** Natural resources forum.

STIEGLITZ, S., & BROCKMANN, T., 2013 — **The impact of smartphones on e-participation.** 2013 46th Hawaii international conference on system sciences.

STIGLITZ, J. E., 1974 — Growth with exhaustible natural resources: the competitive economy. **The Review of Economic Studies**, 41, 139-152.

STIGLITZ, J. E., 2012 — Macroeconomic fluctuations, inequality, and human development. **Journal of Human Development and Capabilities**, 13(1), 31-58.

STODDART, H., 2011 — **A pocket guide to sustainable development governance.** Commonwealth Secretariat Stakeholder Forum

STOKEY, N. L., 1998 — Are there limits to growth? **International economic review**, 1-31.

STOKMAN, F. N., 2004 — **What binds us when with whom? Content and structure in social network analysis. Extended version of keynote at the sunbelt xxiv.** International social network conference. Portoroz (Slovenia).

STOSSEL, Z., KISSINGER, M., & MEIR, A., 2015 — Measuring the biophysical dimension of urban sustainability. **Ecological economics**, 120, 153-163.

STRATIGEA, A., LEKA, A., & NICOLAIDES, C., 2017 — Small and medium-sized cities and insular communities in the Mediterranean: coping with sustainability challenges in the smart city context. **Smart Cities in the Mediterranean** (pp. 3-29). Springer.

SUAIDEN, E. J., 2003 — **The social impact of public libraries.** Library review.

SUHARDI, S., SOFIA, A., & ANDRIYANTO, A., 2015 — Evaluating e-Government and Good Governance Correlation. **ITB Journal Publisher**, LPPM ITB, 9(3).

SUMMIT, G., 2015 — **Smart Cities: Regional Perspective.** In: The Government Summit-Arab Region Dubai: UAE.

| | |
|---|---|
| SUNDAR, I., 2006 | **Environment & Sustainable Development.** APH Publishing. |
| SWAIN, R. B., 2018 | **A critical analysis of the sustainable development goals**. In Handbook of sustainability science and research (pp. 341-355). Springer. |
| SWAIN, R. B., & KARIMU, A., 2020 | Renewable electricity and sustainable development goals in the EU. **World Development**, 125, 104693. |
| SWAIN, R. B., & RANGANATHAN, S., 2021 | Modeling interlinkages between sustainable development goals using network analysis. **World Development**, 138, 105136. |
| SWANEY, J. A., 1987 | Elements of a neoinstitutional environmental economics. Journal of Economic Issues, 21(4), 1739-1779. |
| TAN, F., & LU, Z., 2016 | Assessing regional sustainable development through an integration of nonlinear principal component analysis and Gram Schmidt orthogonalization. **Ecological indicators**, 63, 71-81. |
| TANDA, A., DE MARCO, A., & ROSSO, M., 2017 | **Evaluating the impact of smart city initiatives.** The 6th international conference on smart cities and green ICT systems. |
| TEECE, D. J., 1986 | Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. **Research Policy**, 15(6), 285-305. |
| TEKIN BILBIL, E., 2017 | The operationalizing aspects of smart cities: The case of Turkey's smart strategies. Journal of the knowledge economy, 8(3), 1032-1048. |
| TEODORESCU, A.-M., 2012 | **Links between the pillars of sustainable development.** Annals of the University of Craiova, Economic Sciences Series, 1. |
| THELLUFSEN, J. Z., LUND, H., SORKNÆS, P., ØSTERGAARD, P., CHANG, M., DRYSDALE, D., NIELSEN, S., DJØRUP, S., & SPERLING, K., 2020 | Smart energy cities in a 100% renewable energy context. Renewable and Sustainable Energy Reviews, 129, 109922. |
| THOITS, P. A., & HEWITT, L. N., 2001 | Volunteer work and well-being. **Journal of health and social behavior**, 115-131. |
| THOMPSON, E. M., 2016 | What makes a city 'smart'? **International Journal of Architectural Computing**, 14(4), 358-371. |
| THOMPSON, H., 2017 | **Oil and the western economic crisis.** Springer. |
| THUZAR, M., 2011 | Urbanization in Southeast Asia: developing smart cities for the future? **Regional outlook**, 96. |

TIARAWUT, S., 2013 Mobile technology: Opportunity for entrepreneurship. **Wireless personal communications**, 69(3), 1025-1031.

TIPPS, C., 1976 **Modernisation Theory and the Comparative Study of Societies.** Comparative Modernisation: A Reader. New York: Free Press.

TIPPS, D. C., 1973 Modernization theory and the comparative study of national societies: A critical perspective. **Comparative studies in society and history**, 15(2), 199-226.

TOBIN, J., 1965 Money and economic growth. Econometrica: **Journal of the Econometric Society**, 671-684.

TODARO, M. P., & SMITH, S. C., 2020 **Economic development.** Pearson UK.

TÖDTLING, F., LEHNER, P., & TRIPPL, M., 2006 Innovation in knowledge intensive industries: The nature and geography of knowledge links. **European planning studies**, 14(8), 1035-1058.

TOLBERT, C. J., & MOSSBERGER, K., 2006 The effects of e-government on trust and confidence in government. **Public administration review,** 66(3), 354-369.

TOLI, A. M., & MURTAGH, N., 2020 The concept of sustainability in smart city definitions. **Frontiers in Built Environment,** 6, 77.

TOPPETA, D., 2010 The smart city vision: how innovation and ICT can build smart,“livable”, sustainable cities. **The innovation knowledge foundation**, 5, 1-9.

TOSUN, J., & LEININGER, J., 2017 Governing the interlinkages between the sustainable development goals: Approaches to attain policy integration. **Global Challenges,** 1(9), 1700036.

TOWNSEND, A. M., 2013 **Smart cities: Big data, civic hackers, and the quest for a new utopia**. WW Norton & Company.

TRANOS, E., & GERTNER, D., 2012 Smart networked cities? Innovation: The European J**ournal of Social Science Research,** 25(2), 175-190.

TRINDADE, E. P., HINNIG, M. P. F., MOREIRA DA COSTA, E., MARQUES, J. S., BASTOS, R. C., & YIGITCANLAR, T., 2017 Sustainable development of smart cities: A systematic review of the literature. **Journal of Open Innovation: Technology, Market, and Complexity**, 3(3), 11.

TU, Z., HU, T., & SHEN, R., 2019 Evaluating public participation impact on environmental protection and ecological efficiency in China: Evidence from PITI disclosure. **China Economic Review**, 55, 111-123.

TUGCU, C. T., & TIWARI, A. K., 2016 Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS. **Renewable and Sustainable Energy Reviews**, 65, 610-616.

TURNER, R. K., 1993 Sustainability: principles and practice. **Sustainable Environmental Economics and Management**

TUSALEM, R. F., 2007 A boon or a bane? The role of civil society in third-and fourth-wave democracies. **International Political Science Review**, 28(3), 361-386.

TÜZÜNKAN, D., 2017 The relationship between innovation and tourism: the case of smart tourism. International Journal of Applied Engineering Research, 12(23), 13861-13867.

UDDIN, M., & RAHMAN, A. A., 2012 Energy efficiency and low carbon enabler green IT framework for data centers considering green metrics. **Renewable and Sustainable Energy Reviews**, 16(6), 4078-4094.

UKAOGO, P. O., EWUZIE, U., & ONWUKA, C. V., 2020 Environmental pollution: causes, effects, and the remedies. **Microorganisms for sustainable environment and health** (pp. 419-429). Elsevier.

UNITED NATIONS EDUCATIONAL, S., & ORGANIZATION, C., 2016 Global education monitoring report summary 2016: education for people and planet: creating sustainable futures for all.

VAKHITOVA, G., & PAVLENKO, T., 2010 I**nnovation and productivity: A firm level study of Ukrainian manufacturing sector.** Discussion Papers, 27.

VAN DEN BERG, M., WENDEL-VOS, W., VAN POPPEL, M., KEMPER, H., VAN MECHELEN, W., & MAAS, J., 2015 Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. **Urban Forestry & Urban Greening**, 14(4), 806-816.

VAN HOVE, L., JACOBS, C., HEUSINKVELD, B., ELBERS, J., VAN DRIEL, B., & HOLTSLAG, A., 2015 Temporal and spatial variability of urban heat island and thermal comfort within the Rotterdam agglomeration. **Building and Environment**, 83, 91-103.

VAN WINDEN, W., 2001 The end of social exclusion? On information technology policy as a key to social inclusion in large European cities. **Regional Studies**, 35(9), 861-877.

VAN WINDEN, W., & DE CARVALHO, L., 2017 **Cities and digitalization. How digitalization changes cities: innovation for the urban economy of tomorrow.** Amsterdam: Amsterdam University of Applied Sciences.

VAN ZANTEN, J. A., & VAN TULDER, R., 2021 Analyzing companies' interactions with the Sustainable Development Goals through network analysis: Four corporate sustainability imperatives. **Business Strategy and the Environment**, 30(5), 2396-2420.

VAN ZANTEN, J. A., & VAN TULDER, R., 2021 Towards nexus-based governance: defining interactions between economic activities and Sustainable Development Goals (SDGs). International **Journal of Sustainable Development & World Ecology,** 28(3), 210-226.

VANDER-MERWE, I., & VAN-DER-MERWE, J., 1999 **Sustainable development at the local level: An introduction to local agenda 21**. Pretoria: Department of environmental affairs and tourism. Duran, CD, Gogan, LM, Artene, A. & Duran, 2015, 806-811.

VANOLO, A., 2016 Is there anybody out there? The place and role of citizens in tomorrow's smart cities. **Futures**, 82, 26-36.

VAQUERO-GARCÍA, A., ÁLVAREZ-GARCÍA, J., & PERIS-ORTIZ, M., 2017 Urban models of sustainable development from the economic perspective: Smart cities. **Sustainable Smart Cities,** pp. 15-29. Springer.

VARE, P., & SCOTT, W., 2007 Learning for a change: Exploring the relationship between education and sustainable development. J**ournal of Education for Sustainable Development**, 1(2), 191-198.

VARKEY, P., & ATHYAL, V. P., 2005 Service delivery innovations at Mayo Clinic. **Minnesota medicine**, 88(12), 39-42.

VATALIS, K. I., MANOLIADIS, O. G., & CHARALAMPIDES, G., 2011 Assessment of the economic benefits from sustainable construction in Greece. **International Journal of Sustainable Development & World Ecology**, 18(5), 377-383.

VATN, A., 2015 **Environmental governance: institutions, policies and actions.** Edward Elgar Publishing.

VEERARAGHAVAN, V., 2009 Entrepreneurship and innovation. **Asia Pacific Business Review**, 5(1), 14-20.

VERBA, S., SCHLOZMAN, K. L., & BRADY, H. E., 1995 **Voice and equality: Civic voluntarism in American politics.** Harvard University Press.

VIITANEN, J., & KINGSTON, R., 2014 Smart cities and green growth: outsourcing democratic and environmental resilience to the global technology sector. **Environment and Planning**, 46(4), 803-819.

VISVIZI, A., LYTRAS, M. D., DAMIANI, E., & MATHKOUR, H., 2018 Policy making for smart cities: Innovation and social inclusive economic growth for sustainability. **Journal of Science and Technology Policy Management.**

VIVARELLI, M., & PIANTA, M., 2000 **The employment impact of innovation.** Taylor & Francis.

VO, D. H., 2021 Renewable energy and population growth for sustainable development in the Southeast Asian countries. **Energy, Sustainability and Society**, 11(1), 1-15.

VON HALDENWANG, C., 2004 Electronic government (e-government) and development. **The European journal of development research**, 16(2), 417-432.

VOS, R. O., 1997 Introduction: competing approaches to sustainability: Dimensions of Controversy. **Flashpoints in Environmental Policymaking: Controversies in Achieving Sustainably**, 1-26.

VOS, R. O., 2007 Defining sustainability: a conceptual orientation. Journal of Chemical Technology & Biotechnology: International Research in Process, **Environmental & Clean Technology**, 82(4), 334-339.

WAAGE, J., YAP, C., BELL, S., LEVY, C., MACE, G., PEGRAM, T., UNTERHALTER, E., DASANDI, N., HUDSON, D., & KOCK, R., 2015 Governing the UN Sustainable Development Goals: interactions, infrastructures, and institutions. **The Lancet Global Health**, 3(5), e251-e252.

WACHSMUTH, D., & ANGELO, H., 2018 Green and gray: New ideologies of nature in urban sustainability policy. Annals of the American Association of Geographers, 108(4), 1038-1056.

WAHEDUZZAMAN, W., & KHANDAKER, S., 2022 E-participation for combating corruption, increasing voice and accountability, and developing government effectiveness: A cross-country data analysis. Australian **Journal of Public Administration.**

WAKABI, W., & GRÖNLUND, Å., 2015 **Citizen-to-citizen vs. Citizen-to-government E-participation in Uganda: implications for research and practice.** International conference on electronic participation.

WANG, M., & ZHOU, T., 2022 Understanding the dynamic relationship between smart city implementation and urban sustainability. **Technology in Society**, 70, 102018.

WANG, M. L., WANG, W., DU, S. Y., LI, C. F., & HE, Z., 2020 Causal relationships between carbon dioxide emissions and economic factors: Evidence from China. **Sustainable development**, 28(1), 73-82.

WARFORD, J. J., MUNASINGHE, M., & CRUZ, W., 1997 **The greening of economic policy reform.** World Bank Publications.

WARKENTIN, C., 2001 **Reshaping world politics: NGOs, the Internet, and global civil society**. Rowman & Littlefield.

WARKENTIN, M., GEFEN, D., PAVLOU, P. A., & ROSE, G. M., 2002 Encouraging citizen adoption of e-government by building trust. **Electronic markets**, 12(3), 157-162.

WASHBURN, D., SINDHU, U., BALAOURAS, S., DINES, Helping CIOs understand “smart city” initiatives. **Growth**, 17(2), 1-17.

R. A., HAYES, N., & NELSON, L. E., 2009

WCED, S. W. S., 1987 **World commission on environment and development.** Our common future, 17(1), 1-91.

WEBER, L. M., LOUMAKIS, A., & BERGMAN, J., 2003 Who participates and why? An analysis of citizens on the Internet and the mass public. Social science computer review, 21(1), 26-42.

WEBSTER, A., 1984 Theories of Underdevelopment. Introduction to the Sociology of Development (pp. 64-93). Springer.

WEGERIF, R., 2010 **Mind expanding: teaching for thinking and creativity in primary education: Teaching for Thinking and Creativity in Primary Education**. McGraw-Hill Education (UK).

WEITZ, N., CARLSEN, H., NILSSON, M., & SKÅNBERG, K., 2018 Towards systemic and contextual priority setting for implementing the 2030 Agenda. Sustainability Science, 13(2), 531-548.

WEST, D., 2012 How mobile devices are transforming healthcare. **Issues in technology innovation**, 18(1), 1-11.

WEST, D. M., 2004 E-government and the transformation of service delivery and citizen attitudes. **Public administration review**, 64(1), 15-27.

WESTERLUND, J., 2008 Panel cointegration tests of the Fisher effect. **Journal of Applied Econometrics**, 23(2), 193-233.

WIEBE, K. S., 2012 **Quantitative assessment of sustainable development and growth in sub-Saharan Africa.** Maastricht University.

WIIG, A., 2015 IBM's smart city as techno-utopian policy mobility. **City**, 19(2-3), 258-273.

WILKINSON, R., & PICKETT, K., 2011 Greater Equality: The Hidden Key to Better Health and Higher Scores. **American Educator**, 35(1), 5-9.

WILLIAMSON, O. E., 2013 **The transaction cost economics project.** Elgar.

WILLIS, K., 2011 **Theories and practices of development.** Routledge.

WILSON, E. O., 1989 Threats to biodiversity. **Scientific American**, 261(3), 108-117.

WINTERS, J. V., 2011 Why are smart cities growing? Who moves and who stays. **Journal of Regional Science**, 51(2), 253-270.

WOLCH, J. R., BYRNE, J., & NEWELL, J. P., 2014 Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. **Landscape and urban planning**, 125, 234-244.

WOODCRAFT, S., HACKETT, T., & CAISTOR-ARENDAR, L., 2011 **Design for social sustainability: A framework for creating thriving new communities.** Young Foundation.

| | |
|---|---|
| WU, J., 2014 | Urban ecology and sustainability: The state-of-the-science and future directions. **Landscape and urban planning**, 125, 209-221. |
| WU, W.-L., 2017 | Institutional Quality and Air Pollution: International Evidence. **International Journal of Business & Economics**, 16(1). |
| WU, Y., HEERINK, N., & YU, L., 2020 | Real estate boom and resource misallocation in manufacturing industries: Evidence from China. China Economic Review, 60, 101400. |
| WU, Z., PAN, Y., YE, Q., & KONG, L., 2016 | The City Intelligence Quotient (City IQ) evaluation system: conception and evaluation. **Engineering**, 2(2), 196-211. |
| XAVIER-OLIVEIRA, E., LAPLUME, A. O., & PATHAK, S., 2015 | What motivates entrepreneurial entry under economic inequality? The role of human and financial capital. **Human Relations**, 68(7), 1183-1207. |
| XU, G., & YANO, G., 2017 | How does anti-corruption affect corporate innovation? Evidence from recent anti-corruption efforts in China. **Journal of Comparative Economics,** 45(3), 498-519. |
| YADAV, G., MANGLA, S. K., LUTHRA, S., & RAI, D. P., 2019 | Developing a sustainable smart city framework for developing economies: An Indian context. **Sustainable cities and society**, 47, 101462. |
| YAO, T., HUANG, Z., & ZHAO, W., 2020 | Are smart cities more ecologically efficient? Evidence from China. Sustainable cities and society, 60, 102008. |
| YE, W., LI, X., & CHEN, Q., 2018 | The impact of floating population on urban entrepreneurial activity: Mechanism and evidence. **Economic Research**, 6, 157-170. |
| YEH, H., 2017 | The effects of successful ICT-based smart city services: From citizens' perspectives. Government information quarterly, 34(3), 556-565. |
| YI, M. H., & CHOI, C., 2005 | The effect of the internet on inflation: Panel data evidence**. Journal of Policy Modeling**, 27(7), 885-889. |
| YI, P., LI, W., & ZHANG, D., 2019 | Assessment of city sustainability using MCDM with interdependent criteria weight. Sustainability, 11(6), 1632. |
| YIGITCANLAR, T., 2018 | Smart city, knowledge city, sustainable city-the brand soup of contemporary cities. **International Journal of Knowledge-Based Development,** 9(1), 1-5. |
| YIGITCANLAR, T., KAMRUZZAMAN, M., BUYS, L., IOPPOLO, G., SABATINI-MARQUES, J., DA COSTA, E. M., & YUN, J. J., 2018 | Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. **Cities**, 81. |

| | |
|---|---|
| YIGITCANLAR, T., FOTH, M., & KAMRUZZAMAN, M., 2019 | Towards post-anthropocentric cities: Reconceptualizing smart cities to evade urban ecocide. **Journal of urban technology**, 26(2), 147-152. |
| YIGITCANLAR, T., HAN, H., KAMRUZZAMAN, M., IOPPOLO, G., & SABATINI-MARQUES, J., 2019 | The making of smart cities: Are Songdo, Masdar, Amsterdam, San Francisco and Brisbane the best we could build? **Land use policy,** 88, 104187. |
| YIGITCANLAR, T., & KAMRUZZAMAN, M., 2018 | Does smart city policy lead to sustainability of cities? **Land use policy**, 73, 49-58. |
| YIGITCANLAR, T., & LEE, S. H., 2014 | Korean ubiquitous-eco-city: A smart-sustainable urban form or a branding hoax? **Technological Forecasting and Social Change**, 89, 100-114. |
| YIGITCANLAR, T., & TERIMAN, S., 2015 | Rethinking sustainable urban development: towards an integrated planning and development process. **International Journal of Environmental Science and Technology**, 12(1), 341-352. |
| YOUNIS, F., & CHAUDHARY, M. A., 2017 | Sustainable Development: Economic, Social, and Environmental Sustainability in Asian Economies. **Forman Journal of Economic Studies** , Vol. 15, (2019): pp. 87-114. |
| ZHAI, T., & CHANG, Y.-C., 2019 | The contribution of China's civil law to sustainable development: Progress and prospects. **Sustainability**, 11(1), 294. |
| ZHENG, Y., & SCHACHTER, H. L., 2017 | Explaining citizens' E-participation use: The role of perceived advantages. **Public Organization Review**, 17(3), 409-428. |
| ZHOU, H., DEKKER, R., & KLEINKNECHT, A., 2011 | Flexible labour and innovation performance: evidence from longitudinal firm-level data. **Industrial and Corporate Change**, 20(3), 941-968. |
| ZHOU, H., WANG, Y., GAO, L., & WU, H., 2020 | How housing price fluctuation affects resource allocation: Evidence from China. **Emerging Markets Finance and Trade**, 56(13), 3084-3094. |
| ZHU, M., & LU, S., 2022 | Effects of ICT diffusion on environmental pollution: analysis of industrial reallocation effects in China. **Environmental Science and Pollution Research**, 1-22. |
| ZILBERMAN, D., 2014 | Fellows Address: The economics of sustainable development. **American Journal of Agricultural Economics**, 96(2), 385-396. |
| ZIMMERMAN, L., 1962 | **The Distribution of World Income,** 1860-1960//Essays in Unbalanced Growth. by E. de Vries. The Hague, Netherlands: Mouton. |

ZUGRAVU, C.-A., PARVU, M., PATRASCU, D., & STOIAN, A., 2009 Correlations between lead and cadmium pollution of honey and environmental heavy metal presence in two Romanian counties. **Bulletin UASVM Agriculture**, 66(2).

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.

# APPENDIX A

**Table A.1:** Centrality results (2005-2019).

| Indicator | Theme | Weighted Indegree | Weighted Outdegree | Weighted Degree | Indegree | Outdegree | Degree | Closness Centrality | Betweenness Centrality | Eigen Centrality |
|---|---|---|---|---|---|---|---|---|---|---|
| **Government effectiveness** | Gov | 2.6193 | 6.1201 | 8.7394 | 6 | 21 | 27 | 0.818182 | 64.17566 | 0.324684 |
| **Digital Governance** | Gov | 3.3768 | 5.0166 | 8.3934 | 6 | 10 | 16 | 0.6 | 19.28947 | 0.263799 |
| **ICT infrastructure** | Tech | 1.8086 | 5.955 | 7.7636 | 4 | 20 | 24 | 0.794118 | 26.26054 | 0.213339 |
| **Business sophistication** | Economy | 2.1194 | 5.3173 | 7.4367 | 7 | 13 | 20 | 0.658537 | 20.15877 | 0.387782 |
| **Innovation** | Economy | 2.8451 | 4.5642 | 7.4093 | 9 | 17 | 26 | 0.72973 | 154.6938 | 0.533518 |
| **Government transparency** | Outcome | 1.8703 | 5.3899 | 7.2602 | 5 | 17 | 22 | 0.72973 | 28.7877 | 0.319467 |
| **ICT Usage** | Tech | 4.7671 | 2.4031 | 7.1702 | 11 | 9 | 20 | 0.529412 | 49.06433 | 0.542947 |
| **E-Participation Index** | Gov | 5.3687 | 1.3306 | 6.6993 | 13 | 4 | 17 | 0.519231 | 31.62733 | 0.569293 |
| **Civil society participation** | Gov | 3.3526 | 2.502 | 5.8546 | 9 | 8 | 17 | 0.5625 | 45.72639 | 0.460374 |
| **Education** | Community | 1.026 | 4.2644 | 5.2904 | 6 | 16 | 22 | 0.692308 | 32.26948 | 0.334502 |
| **Quality of Transport Infrastructure** | Infra | 2.8847 | 1.9796 | 4.8643 | 6 | 7 | 13 | 0.473684 | 17.8985 | 0.296729 |
| **Inequality** | Neg. externalities | 2.8026 | 1.7757 | 4.5783 | 14 | 7 | 21 | 0.490909 | 33.08977 | 0.744965 |
| **Employment in high-tech** | Economy | 1.8671 | 2.2426 | 4.1097 | 7 | 11 | 18 | 0.627907 | 38.58216 | 0.310833 |
| **Health** | Outcome | 3.7768 | 0.1377 | 3.9145 | 14 | 1 | 15 | 0.317647 | 12.7 | 0.759771 |
| **Renewable energy consumption** | Infra | 2.6656 | 0.9266 | 3.5922 | 8 | 6 | 14 | 0.465517 | 17.77151 | 0.386672 |
| **Env. Sustainability** | Outcome | 3.293 | 0.1473 | 3.4403 | 17 | 2 | 19 | 0.325301 | 15.62778 | 0.857516 |
| **Flexibility in labour market** | Outcome | 2.622 | 0.7375 | 3.3595 | 12 | 7 | 19 | 0.54 | 43.20096 | 0.637077 |
| **Productivity** | Outcome | 2.7726 | 0.4913 | 3.2639 | 18 | 2 | 20 | 0.45 | 115.1012 | 1 |
| **Patents in environment-related technologies** | Infra | 0.9733 | 2.2166 | 3.1899 | 5 | 4 | 9 | 0.364865 | 1.427778 | 0.243206 |
| **Entrepreneurship** | Economy | 1.8958 | 0.9806 | 2.8764 | 14 | 6 | 20 | 0.54 | 29.22583 | 0.759713 |
| **Diminishing Freedom** | Neg. externalities | 1.7347 | 1.1415 | 2.8762 | 3 | 2 | 5 | 0.380282 | 0.25 | 0.174983 |
| **Digital Proficiency** | Community | 0.8906 | 1.8471 | 2.7377 | 3 | 5 | 8 | 0.509434 | 2.580891 | 0.134562 |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Digital Divide** | Neg. externalities | 1.5667 | 1.1264 | 2.6931 | 5 | 5 | 10 | 0.482143 | 2.665079 | 0.287868 |
| **Creativity** | Community | 0.7107 | 1.9086 | 2.6193 | 4 | 8 | 12 | 0.529412 | 5.618254 | 0.253305 |
| **Safety** | Outcome | 1.2212 | 0.9658 | 2.187 | 5 | 5 | 10 | 0.473684 | 3.606746 | 0.34067 |
| **Municipal Waste Treated** | Infra | 1.7514 | 0.3413 | 2.0927 | 5 | 2 | 7 | 0.254717 | 0.333333 | 0.224601 |
| **Privacy Issues** | Neg. externalities | 0.5736 | 0.9861 | 1.5597 | 3 | 3 | 6 | 0.421875 | 2.266667 | 0.13943 |
| **Urban efficiency** | Outcome | 0.2719 | 0.6127 | 0.8846 | 2 | 3 | 5 | 0.3375 | 0 | 0.070999 |

**Table A.2:** Centrality results (2005).

| Indicator | Theme | Indegree | Outdegree | Degree | Weighted Indegree | Weighted Outdegree | Weighted Degree | Closness Centrality | Betweenness Centrality | Eigen Centrality |
|---|---|---|---|---|---|---|---|---|---|---|
| **Government effectiveness** | Gov | 6 | 21 | 27 | 2.6814 | 5.0692 | 7.7506 | 0.818182 | 63.15111 | 0.323675 |
| **Innovation** | Economy | 9 | 17 | 26 | 2.2115 | 4.4451 | 6.6566 | 0.72973 | 155.4684 | 0.533074 |
| **ICT Usage** | Tech | 11 | 9 | 20 | 3.9989 | 2.5808 | 6.5797 | 0.529412 | 49.55372 | 0.554465 |
| **Civil society participation** | Gov | 9 | 8 | 17 | 3.3478 | 3.2037 | 6.5515 | 0.5625 | 43.92561 | 0.455978 |
| **ICT infrastructure** | Tech | 4 | 20 | 24 | 1.1416 | 5.4021 | 6.5437 | 0.794118 | 26.2752 | 0.214105 |
| **E-Participation Index** | Gov | 13 | 4 | 17 | 5.0214 | 1.3723 | 6.3937 | 0.519231 | 31.85943 | 0.578025 |
| **Innovation & sophistication factors** | Economy | 7 | 13 | 20 | 1.7531 | 4.4061 | 6.1592 | 0.658537 | 20.26372 | 0.386372 |
| **Inequality** | Neg. externalities | 13 | 7 | 20 | 3.9966 | 2.0861 | 6.0827 | 0.490909 | 28.41047 | 0.714984 |
| **Digital Governance** | Gov | 6 | 10 | 16 | 2.1703 | 3.8645 | 6.0348 | 0.6 | 22.91774 | 0.264139 |
| **Education** | Community | 6 | 16 | 22 | 1.3554 | 4.5097 | 5.8651 | 0.692308 | 32.30599 | 0.335821 |
| **Employment in high-tech** | Economy | 7 | 11 | 18 | 2.3365 | 3.1144 | 5.4509 | 0.627907 | 38.3915 | 0.312129 |
| **Renewable energy consumption** | Infra | 8 | 6 | 14 | 3.6506 | 1.5161 | 5.1667 | 0.465517 | 17.99337 | 0.384803 |
| **Productivity** | Outcome | 18 | 2 | 20 | 4.1227 | 0.4263 | 4.549 | 0.45 | 115.427 | 1 |
| **Government transparency** | Outcome | 5 | 17 | 22 | 0.7188 | 3.7594 | 4.4782 | 0.72973 | 27.56038 | 0.29528 |
| **Entrepreneurship** | Economy | 14 | 6 | 20 | 3.2224 | 1.1483 | 4.3707 | 0.54 | 31.22621 | 0.756595 |
| **Flexibility in labour market** | Outcome | 12 | 7 | 19 | 2.5159 | 1.6198 | 4.1357 | 0.54 | 43.51628 | 0.642616 |
| **Patents in environment-related technologies** | Infra | 5 | 4 | 9 | 1.6529 | 2.4787 | 4.1316 | 0.364865 | 1.416667 | 0.244192 |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Quality of Transport Infrastructure** | Infra | 6 | 7 | 13 | 2.245 | 1.7142 | 3.9592 | 0.465517 | 17.80597 | 0.294622 |
| **Safety** | Outcome | 5 | 5 | 10 | 2.0103 | 1.7868 | 3.7971 | 0.473684 | 4.171429 | 0.335049 |
| **Health** | Outcome | 14 | 1 | 15 | 3.5161 | 0.2282 | 3.7443 | 0.317647 | 12.7 | 0.755073 |
| **Creativity** | Community | 4 | 8 | 12 | 1.2359 | 2.1237 | 3.3596 | 0.54 | 5.586508 | 0.255507 |
| **Env. Sustainability** | Outcome | 17 | 2 | 19 | 2.6979 | 0.4184 | 3.1163 | 0.325301 | 15.7746 | 0.8555 |
| **Digital Proficiency** | Community | 3 | 5 | 8 | 0.9593 | 2.0611 | 3.0204 | 0.5 | 1.32732 | 0.135311 |
| **Digital Divide** | Neg. externalities | 6 | 5 | 11 | 1.1586 | 1.795 | 2.9536 | 0.482143 | 4.954701 | 0.331584 |
| **Municipal Waste Treated** | Infra | 5 | 2 | 7 | 1.9613 | 0.5004 | 2.4617 | 0.254717 | 0.333333 | 0.222652 |
| **Diminishing Freedom/Democracy** | Neg. externalities | 3 | 2 | 5 | 1.1172 | 0.863 | 1.9802 | 0.385714 | 0.25 | 0.176555 |
| **Privacy Issues** | Neg. externalities | 3 | 3 | 6 | 0.3309 | 0.6687 | 0.9996 | 0.421875 | 1.433333 | 0.158733 |
| **Urban efficiency** | Outcome | 2 | 3 | 5 | 0.3809 | 0.3491 | 0.73 | 0.3375 | 0 | 0.071185 |

**Table A.3:** Centrality results (2019).

| Indicator | Theme | Indegree | Outdegree | Degree | Weighted Indegree | Weighted Outdegree | Weighted Degree | Closness Centrality | Betweenness Centrality | Eigen Centrality |
|---|---|---|---|---|---|---|---|---|---|---|
| **Innovation** | Economy | 9 | 17 | 26 | 2.9761 | 5.8176 | 8.7937 | 0.72973 | 153.9897 | 0.538304 |
| **Business sophistication** | Economy | 8 | 13 | 21 | 2.2634 | 5.7216 | 7.985 | 0.658537 | 20.63805 | 0.41852 |
| **Government effectiveness** | Gov | 5 | 21 | 26 | 1.6738 | 5.2271 | 6.9009 | 0.818182 | 49.94504 | 0.254091 |
| **ICT Usage** | Tech | 11 | 9 | 20 | 3.8156 | 2.5126 | 6.3282 | 0.529412 | 50.65424 | 0.538776 |
| **ICT infrastructure** | Tech | 4 | 20 | 24 | 1.5672 | 4.5287 | 6.0959 | 0.794118 | 26.72692 | 0.209135 |
| **Digital Governance** | Gov | 6 | 10 | 16 | 1.8202 | 3.9824 | 5.8026 | 0.6 | 26.18801 | 0.263712 |
| **Education** | Community | 6 | 16 | 22 | 1.502 | 4.2306 | 5.7326 | 0.692308 | 31.57842 | 0.316487 |
| **Productivity** | Outcome | 18 | 2 | 20 | 4.8926 | 0.4781 | 5.3707 | 0.45 | 115.2455 | 1 |
| **Inequality** | Neg. externalities | 13 | 7 | 20 | 2.9808 | 2.1727 | 5.1535 | 0.490909 | 32.15781 | 0.692689 |
| **Employment in high-tech** | Economy | 7 | 11 | 18 | 1.9906 | 2.9192 | 4.9098 | 0.627907 | 41.43205 | 0.311201 |
| **E-Participation Index** | Gov | 13 | 4 | 17 | 3.6716 | 1.1974 | 4.869 | 0.519231 | 32.8233 | 0.559732 |
| **Renewable energy** | Infra | 8 | 6 | 14 | 3.3117 | 1.4682 | 4.7799 | 0.465517 | 17.73442 | 0.382057 |
| **Env. Sustainability** | Outcome | 17 | 2 | 19 | 4.1524 | 0.5519 | 4.7043 | 0.325301 | 15.62778 | 0.84751 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Quality of Transport Infrastructure** | Infra | 6 | 7 | 13 | 2.3207 | 2.3017 | 4.6224 | 0.473684 | 18.45085 | 0.295153 |
| **Entrepreneurship** | Economy | 14 | 6 | 20 | 3.2269 | 1.3874 | 4.6143 | 0.54 | 24.29528 | 0.756314 |
| **Flexibility in labour market** | Outcome | 12 | 7 | 19 | 3.1212 | 1.2077 | 4.3289 | 0.54 | 44.09228 | 0.637516 |
| **Health** | Outcome | 14 | 1 | 15 | 4.1311 | 0.1122 | 4.2433 | 0.317647 | 12.7 | 0.74632 |
| **Civil society participation** | Gov | 9 | 8 | 17 | 2.3344 | 1.7487 | 4.0831 | 0.5625 | 48.85924 | 0.454319 |
| **Government transparency** | Outcome | 6 | 17 | 23 | 1.2565 | 2.7993 | 4.0558 | 0.72973 | 34.82018 | 0.344505 |
| **Patents in env. technologies** | Infra | 5 | 4 | 9 | 1.4828 | 1.5896 | 3.0724 | 0.364865 | 2.183333 | 0.238485 |
| **Creativity** | Community | 5 | 8 | 13 | 0.9822 | 2.0198 | 3.002 | 0.529412 | 5.685317 | 0.322074 |
| **Privacy Issues** | Neg. externalities | 3 | 3 | 6 | 1.0102 | 1.7724 | 2.7826 | 0.421875 | 1.433333 | 0.147141 |
| **Digital Divide** | Neg. externalities | 5 | 5 | 10 | 1.0919 | 1.664 | 2.7559 | 0.482143 | 3.037302 | 0.251949 |
| **Digital Proficiency** | Community | 3 | 5 | 8 | 0.8227 | 1.6189 | 2.4416 | 0.5 | 1.480891 | 0.12333 |
| **Safety** | Outcome | 5 | 5 | 10 | 0.7736 | 1.3926 | 2.1662 | 0.465517 | 3.637515 | 0.334392 |
| **Municipal Waste Treated** | Infra | 4 | 2 | 6 | 1.2394 | 0.5766 | 1.816 | 0.254717 | 0.333333 | 0.189287 |
| **Diminishing Freedom** | Neg. externalities | 3 | 2 | 5 | 1.0531 | 0.4685 | 1.5216 | 0.380282 | 0.25 | 0.173695 |
| **Urban efficiency** | Outcome | 2 | 3 | 5 | 0.4545 | 0.4517 | 0.9062 | 0.3375 | 0 | 0.070344 |

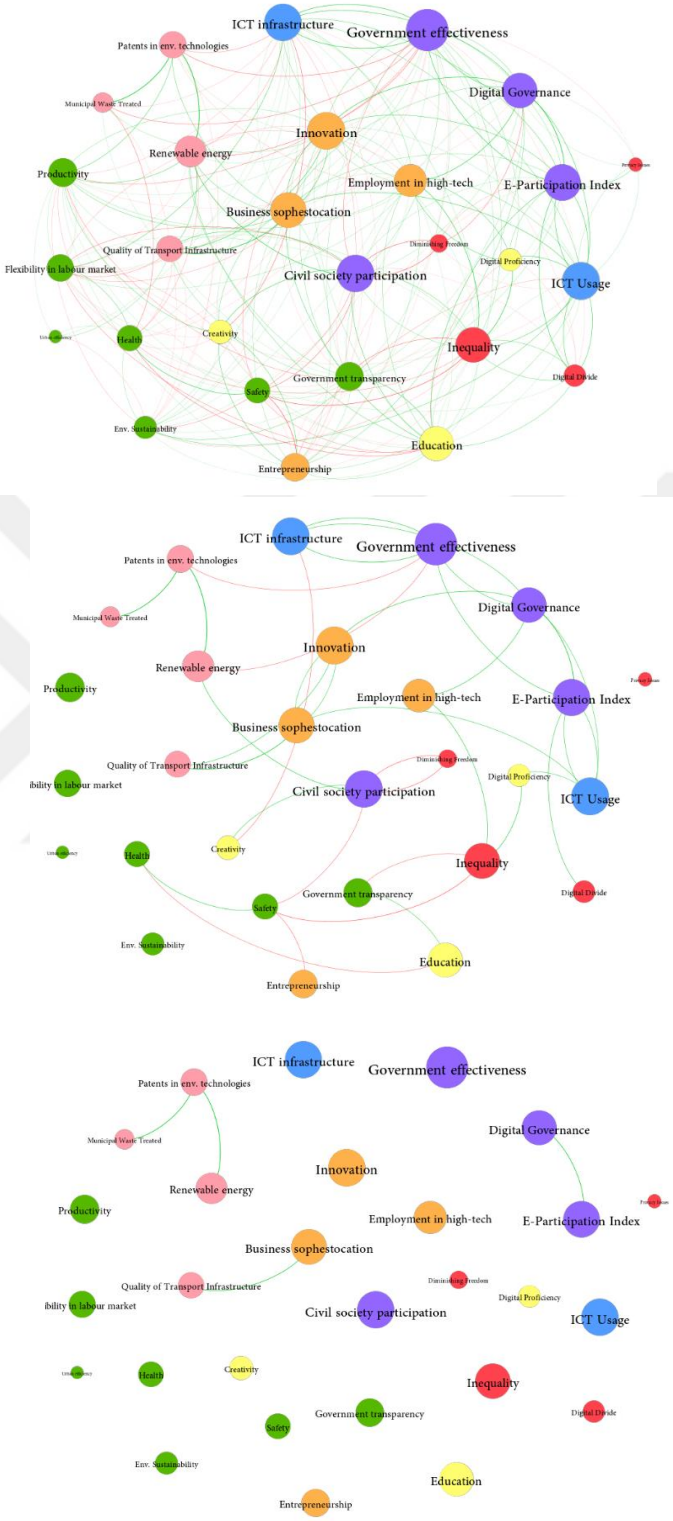



**Figure A.1:** Correlation network for smart city indicators for the 2005 with (a) low threshold, (b) medium threshold, and (c) high threshold.

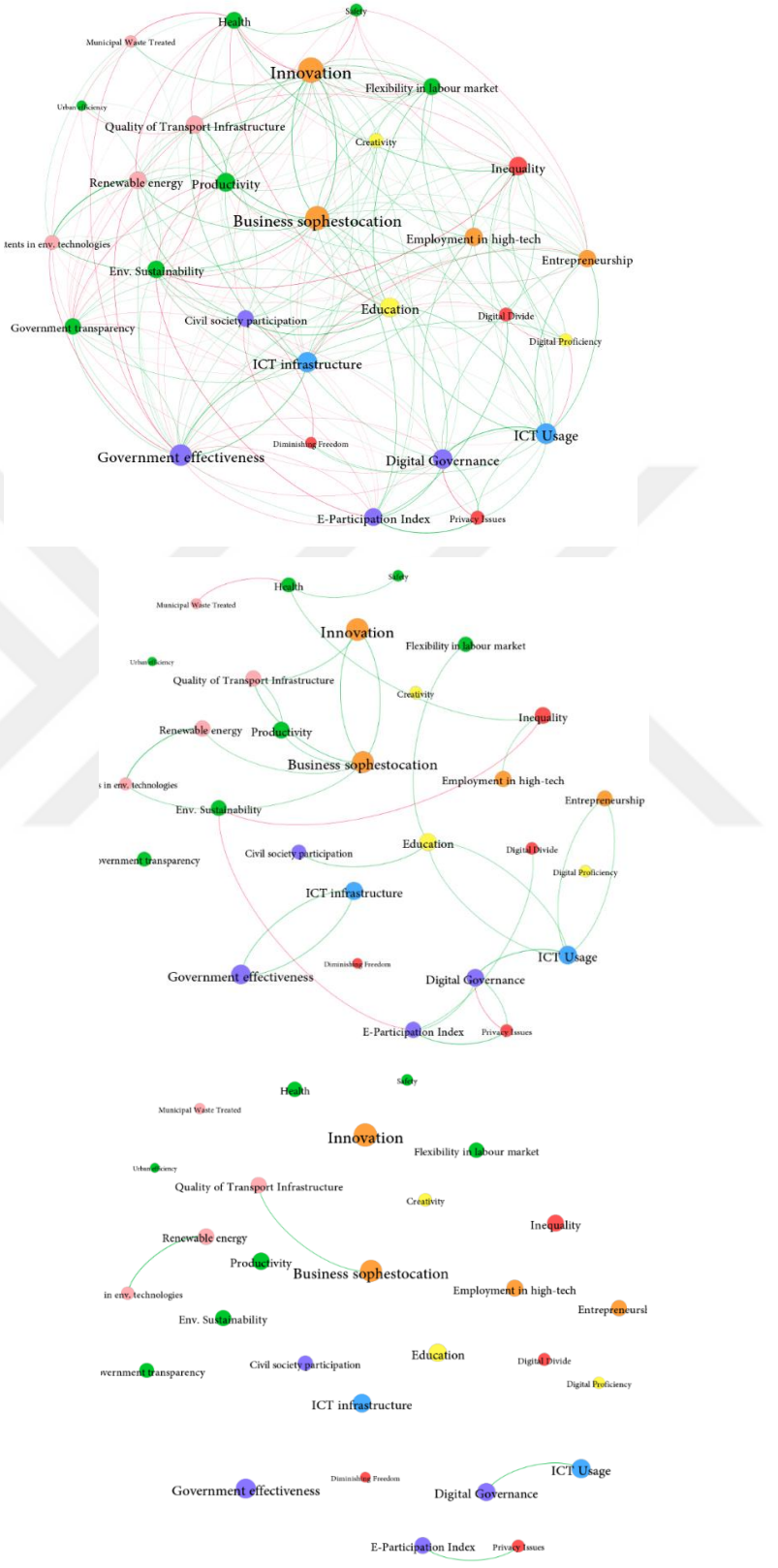



**Figure A.2:** Correlation network for smart city indicators for the 2019 with (a) low threshold, (b) medium threshold, and (c) high threshold.

# APPENDIX B

**Table B.1:** Dynamic scores of urban smartness with respect to the first principal component of DFA on the drivers of smart cities, 2005-2019.

| F1 | Amsterdam | Barcelona | Berlin | Bratislava | Brisbane | Brussels | Copenhagen | Dublin | Frankfurt | Helsinki | London |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 0.372785 | -0.9393 | 0.356271 | -1.00296 | 0.204358 | -0.65136 | -0.24912 | -0.7565 | 0.686875 | -0.2653 | 0.364395 |
| 2006 | 0.370166 | -0.88322 | 0.321958 | -1.02645 | 0.23392 | -0.62603 | -0.21287 | -0.76263 | 0.657141 | -0.2952 | 0.282369 |
| 2007 | 0.376378 | -0.83116 | 0.295722 | -1.04325 | 0.267066 | -0.60222 | -0.18319 | -0.77033 | 0.640612 | -0.3239 | 0.196631 |
| 2008 | 0.378079 | -0.77779 | 0.264623 | -1.03832 | 0.279695 | -0.6006 | -0.15181 | -0.75787 | 0.600044 | -0.32593 | 0.103345 |
| 2009 | 0.373183 | -0.71608 | 0.318417 | -1.03112 | 0.264408 | -0.57143 | -0.24213 | -0.74527 | 0.650656 | -0.336 | 0.154458 |
| 2010 | 0.354068 | -0.61069 | 0.39569 | -1.05516 | 0.297053 | -0.55102 | -0.46787 | -0.73147 | 0.730697 | -0.39268 | 0.262655 |
| 2011 | 0.366196 | -0.64949 | 0.395017 | -1.06561 | 0.296672 | -0.55355 | -0.3177 | -0.73158 | 0.733657 | -0.38783 | 0.262073 |
| 2012 | 0.412083 | -0.705 | 0.467341 | -1.06495 | 0.288915 | -0.56168 | -0.3121 | -0.72786 | 0.798873 | -0.37409 | 0.220155 |
| 2013 | 0.437579 | -0.63027 | 0.448969 | -1.04793 | 0.282885 | -0.5714 | -0.40006 | -0.65305 | 0.77109 | -0.33685 | 0.246772 |
| 2014 | 0.486072 | -0.58956 | 0.38075 | -1.00556 | 0.290242 | -0.5676 | -0.47507 | -0.61011 | 0.70503 | -0.32798 | 0.274138 |
| 2015 | 0.456311 | -0.62343 | 0.377383 | -1.03548 | 0.290255 | -0.57181 | -0.43945 | -0.62195 | 0.705155 | -0.34185 | 0.288372 |
| 2016 | 0.437314 | -0.63334 | 0.382693 | -1.06956 | 0.280454 | -0.57355 | -0.39377 | -0.62899 | 0.70891 | -0.34896 | 0.289288 |
| 2017 | 0.42914 | -0.63948 | 0.390997 | -1.01299 | 0.252422 | -0.59831 | -0.37145 | -0.61385 | 0.724223 | -0.35334 | 0.256936 |
| 2018 | 0.417037 | -0.64352 | 0.401109 | -0.97165 | 0.22606 | -0.61196 | -0.34732 | -0.6103 | 0.722239 | -0.34321 | 0.21733 |
| 2019 | 0.407643 | -0.64911 | 0.410494 | -0.93626 | 0.199773 | -0.63268 | -0.32046 | -0.60878 | 0.730127 | -0.33599 | 0.176951 |

| F1 | Los Angeles | Madrid | Manchester | Melbourne | Milan | Montreal | Munich | New York | Oslo | Paris | Prague |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 0.728118 | -0.91553 | 0.438404 | 0.198545 | -0.13619 | 0.470024 | 0.509317 | 0.655862 | -0.37777 | 0.28479 | -0.91239195 |
| 2006 | 0.698505 | -0.86303 | 0.357643 | 0.228437 | -0.07592 | 0.454496 | 0.475606 | 0.624068 | -0.36742 | 0.340154 | -0.90143403 |
| 2007 | 0.671333 | -0.81585 | 0.278653 | 0.256922 | -0.02081 | 0.433474 | 0.451749 | 0.596244 | -0.35608 | 0.392805 | -0.89320812 |
| 2008 | 0.67306 | -0.76658 | 0.176377 | 0.273778 | -0.08184 | 0.421697 | 0.415768 | 0.597869 | -0.33732 | 0.481149 | -0.85948037 |
| 2009 | 0.630836 | -0.70881 | 0.225746 | 0.256742 | -0.10468 | 0.433552 | 0.467569 | 0.555601 | -0.37977 | 0.433942 | -0.85169813 |
| 2010 | 0.578955 | -0.60375 | 0.334722 | 0.287338 | -0.08865 | 0.449738 | 0.544241 | 0.503465 | -0.46032 | 0.41107 | -0.83933394 |
| 2011 | 0.568491 | -0.6415 | 0.340477 | 0.287398 | -0.05578 | 0.400532 | 0.54462 | 0.489382 | -0.48239 | 0.449671 | -0.89123439 |
| 2012 | 0.580424 | -0.69444 | 0.296255 | 0.281312 | -0.02622 | 0.338756 | 0.61281 | 0.498638 | -0.46368 | 0.487457 | -0.89062166 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2013** | 0.558135 | -0.62061 | 0.326422 | 0.271551 | 0.02682 | 0.31132 | 0.591497 | 0.473889 | -0.45294 | 0.460664 | -0.91019653 |
| **2014** | 0.539841 | -0.58132 | 0.359871 | 0.275594 | 0.070795 | 0.310655 | 0.523219 | 0.45446 | -0.45692 | 0.443829 | -0.92547115 |
| **2015** | 0.532443 | -0.61385 | 0.374828 | 0.276822 | 0.089493 | 0.311229 | 0.521814 | 0.445654 | -0.45585 | 0.420416 | -0.89674137 |
| **2016** | 0.506661 | -0.62345 | 0.38244 | 0.266795 | 0.097422 | 0.307653 | 0.524729 | 0.416874 | -0.46819 | 0.412897 | -0.85302509 |
| **2017** | 0.521277 | -0.62973 | 0.345148 | 0.238846 | 0.086868 | 0.316025 | 0.532683 | 0.429354 | -0.44861 | 0.406472 | -0.83570399 |
| **2018** | 0.542192 | -0.63562 | 0.31033 | 0.213906 | 0.057209 | 0.312129 | 0.538537 | 0.447042 | -0.43535 | 0.413674 | -0.8369687 |
| **2019** | 0.563258 | -0.64092 | 0.271262 | 0.18916 | 0.026171 | 0.307097 | 0.546318 | 0.46396 | -0.42391 | 0.418907 | -0.84367694 |
| **F1** | **Reykjavik** | **Stockholm** | **Sydney** | **Tallinn** | **Tokyo** | **Toronto** | **Vancouver** | **Vienna** | **Warsaw** | **Washington** | **Zürich** |
| **2005** | 0.644104 | -0.2362 | 0.194811 | 0.472188 | 0.247547 | 0.460723 | 0.476948 | -0.69937 | -0.99068 | 0.838409 | -0.4718 |
| **2006** | 0.633191 | -0.20975 | 0.222093 | 0.491889 | 0.224274 | 0.443206 | 0.460081 | -0.64674 | -1.0177 | 0.810357 | -0.44116 |
| **2007** | 0.612485 | -0.17965 | 0.252206 | 0.509937 | 0.198723 | 0.422755 | 0.440787 | -0.59893 | -1.04413 | 0.781312 | -0.41309 |
| **2008** | 0.61773 | -0.1824 | 0.267891 | 0.53419 | 0.196032 | 0.411261 | 0.428218 | -0.588 | -1.03456 | 0.781233 | -0.39954 |
| **2009** | 0.613831 | -0.25412 | 0.252846 | 0.520391 | 0.193372 | 0.423424 | 0.440524 | -0.59361 | -1.00617 | 0.742793 | -0.41139 |
| **2010** | 0.527911 | -0.36033 | 0.285413 | 0.444387 | 0.202386 | 0.439047 | 0.45662 | -0.56257 | -0.99407 | 0.686633 | -0.47418 |
| **2011** | 0.537425 | -0.34577 | 0.285982 | 0.467109 | 0.201628 | 0.389789 | 0.406742 | -0.53954 | -0.98845 | 0.67707 | -0.44952 |
| **2012** | 0.544542 | -0.36205 | 0.278623 | 0.483429 | 0.183736 | 0.327589 | 0.345078 | -0.52388 | -0.9988 | 0.682485 | -0.42314 |
| **2013** | 0.533104 | -0.42521 | 0.267429 | 0.472551 | 0.226933 | 0.299612 | 0.318338 | -0.49798 | -0.9778 | 0.664027 | -0.46529 |
| **2014** | 0.547358 | -0.47682 | 0.272231 | 0.481628 | 0.293402 | 0.298306 | 0.316222 | -0.50765 | -0.93051 | 0.642084 | -0.51116 |
| **2015** | 0.562155 | -0.44058 | 0.275423 | 0.485484 | 0.269506 | 0.298126 | 0.319488 | -0.48904 | -0.88883 | 0.631276 | -0.51278 |
| **2016** | 0.571695 | -0.42464 | 0.268887 | 0.513089 | 0.249247 | 0.294391 | 0.317859 | -0.47345 | -0.84554 | 0.605348 | -0.4982 |
| **2017** | 0.560967 | -0.42721 | 0.243091 | 0.505124 | 0.2453 | 0.303331 | 0.327803 | -0.50406 | -0.84241 | 0.618342 | -0.4572 |
| **2018** | 0.535385 | -0.42582 | 0.217336 | 0.563893 | 0.243515 | 0.300461 | 0.325468 | -0.54722 | -0.82581 | 0.642824 | -0.41293 |
| **2019** | 0.549132 | -0.42535 | 0.19127 | 0.616431 | 0.239866 | 0.294901 | 0.321574 | -0.59351 | -0.81165 | 0.669436 | -0.37144 |

**Table B.2:** Dynamic scores of urban smartness with respect to the second principal component of DFA on the drivers of smart cities, 2005-2019.

| F2 | Amsterdam | Barcelona | Berlin | Bratislava | Brisbane | Brussels | Copenhagen | Dublin | Frankfurt | Helsinki | London |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2005** | -0.04131675 | -0.40967523 | 0.0704335 | -0.64350122 | -0.20836256 | 0.03730309 | 0.91184648 | -0.11542757 | -0.01547644 | 0.85288189 | 0.01892738 |
| **2006** | -0.07223857 | -0.34782518 | 0.04341363 | -0.70299192 | -0.17845221 | 0.10162101 | 0.96790195 | -0.15791619 | -0.01443553 | 0.82544954 | -0.09274339 |
| **2007** | -0.05193183 | -0.28165108 | -0.02075533 | -0.74791605 | -0.10965465 | 0.12395831 | 1.0200825 | -0.15887032 | -0.04978577 | 0.77595346 | -0.19452439 |
| **2008** | -0.07081166 | -0.23057648 | -0.03652994 | -0.71945475 | -0.06952928 | 0.08759387 | 1.0446838 | -0.13869503 | -0.07012838 | 0.79657438 | -0.29444384 |
| **2009** | -0.06676464 | -0.17061881 | 0.00372542 | -0.70391412 | -0.09079006 | 0.13400234 | 0.94181381 | -0.16096206 | -0.03624703 | 0.81332827 | -0.27936164 |
| **2010** | -0.11624 | -0.06894227 | 0.08156756 | -0.68387917 | -0.04157222 | 0.15469666 | 0.58465218 | -0.14889728 | 0.03866577 | 0.75571715 | -0.15177094 |
| **2011** | -0.07540969 | -0.08720149 | 0.0598306 | -0.67523289 | -0.063928 | 0.17104905 | 0.83896437 | -0.11814808 | 0.02117945 | 0.74534262 | -0.14414778 |
| **2012** | 0.02297934 | -0.15842993 | 0.17585219 | -0.65016533 | -0.07694845 | 0.17927475 | 0.81234704 | -0.07541189 | 0.13476746 | 0.74930391 | -0.14575225 |
| **2013** | 0.02550341 | -0.05018664 | 0.16785482 | -0.63354027 | -0.1249424 | 0.15406996 | 0.72591191 | 0.06061101 | 0.12057936 | 0.81200629 | -0.17709458 |
| **2014** | 0.09278194 | -0.033922 | 0.09676196 | -0.57353986 | -0.12392306 | 0.14615334 | 0.6355308 | 0.11227192 | 0.05911366 | 0.77311011 | -0.13923057 |
| **2015** | 0.05956435 | -0.07807384 | 0.07754553 | -0.57948128 | -0.14272486 | 0.15505597 | 0.67104969 | 0.07709137 | 0.05043087 | 0.67578456 | -0.10080548 |
| **2016** | 0.05293277 | -0.07884243 | 0.10003704 | -0.64236995 | -0.1561366 | 0.14546893 | 0.73472455 | 0.05892798 | 0.07068952 | 0.65553607 | -0.11409993 |
| **2017** | 0.05812476 | -0.08937184 | 0.09268067 | -0.56339289 | -0.19984224 | 0.09436387 | 0.73226162 | 0.0738618 | 0.07442656 | 0.65360273 | -0.14842129 |
| **2018** | 0.05502854 | -0.07654956 | 0.09210087 | -0.5527077 | -0.21766654 | 0.09745527 | 0.76469138 | 0.05386985 | 0.05910847 | 0.67955533 | -0.20065861 |
| **2019** | 0.04874826 | -0.06651534 | 0.09429348 | -0.54728227 | -0.24234351 | 0.05864058 | 0.80125219 | -0.00116112 | 0.05571545 | 0.69131687 | -0.22845546 |

| F2 | Los Angeles | Madrid | Manchester | Melbourne | Milan | Montreal | Munich | New York | Oslo | Paris | Prague |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2005** | 0.5791813 | -0.24013505 | 0.05162722 | -0.08811516 | -0.92356451 | 0.04212929 | 0.01561197 | 0.37369118 | 0.59550032 | -0.35760732 | -0.43533754 |
| **2006** | 0.53389575 | -0.19210853 | -0.08805564 | -0.04136978 | -0.82514613 | 0.02532621 | 0.00521224 | 0.31028024 | 0.60450061 | -0.33272959 | -0.38101325 |
| **2007** | 0.5137902 | -0.15122759 | -0.15878989 | 0.01988309 | -0.72765162 | -0.03664673 | -0.04083043 | 0.28450355 | 0.63975395 | -0.32460731 | -0.37501455 |
| **2008** | 0.51000754 | -0.1245468 | -0.24744542 | 0.06802405 | -0.83980344 | -0.05687442 | -0.0586998 | 0.27307464 | 0.63110496 | -0.23136002 | -0.33057414 |
| **2009** | 0.48665121 | -0.08616849 | -0.23708126 | 0.03213973 | -0.85993186 | -0.04977284 | -0.02371639 | 0.23576554 | 0.57874495 | -0.26980337 | -0.32289826 |
| **2010** | 0.42184653 | 0.01701804 | -0.12387609 | 0.0678634 | -0.85058814 | -0.0446541 | 0.04919766 | 0.17219809 | 0.4900286 | -0.24695579 | -0.26260241 |
| **2011** | 0.40850158 | -0.00175989 | -0.10634704 | 0.05254017 | -0.82005274 | -0.09995776 | 0.02960315 | 0.13420518 | 0.46015791 | -0.23346662 | -0.35204135 |
| **2012** | 0.41671632 | -0.07020281 | -0.14533401 | 0.06264525 | -0.78068754 | -0.17990542 | 0.13812399 | 0.12490432 | 0.48317521 | -0.20744737 | -0.36216467 |
| **2013** | 0.40225802 | 0.03219884 | -0.17531051 | 0.01323239 | -0.74233791 | -0.21866008 | 0.13095931 | 0.10280212 | 0.51545747 | -0.25837786 | -0.33228271 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2014** | 0.3926787 | 0.03644337 | -0.13891601 | -0.00089849 | -0.7281163 | -0.21229084 | 0.06030473 | 0.08782352 | 0.49636168 | -0.27827764 | -0.28872535 |
| **2015** | 0.40065579 | -0.00902312 | -0.09954903 | -0.0118065 | -0.68407811 | -0.20257736 | 0.0484348 | 0.09172487 | 0.53250714 | -0.27889534 | -0.2617521 |
| **2016** | 0.37870608 | -0.00872628 | -0.10938961 | -0.02731588 | -0.66533311 | -0.18847853 | 0.06090337 | 0.06064079 | 0.51824744 | -0.28037829 | -0.24548786 |
| **2017** | 0.41533107 | -0.02274176 | -0.16155472 | -0.07052848 | -0.68888938 | -0.13032937 | 0.05664371 | 0.08826284 | 0.56002982 | -0.31298508 | -0.20527015 |
| **2018** | 0.44744113 | -0.01992178 | -0.21750395 | -0.08898957 | -0.78076865 | -0.13700751 | 0.056211 | 0.11085894 | 0.55640231 | -0.27698759 | -0.22387057 |
| **2019** | 0.46201615 | -0.00911601 | -0.26081851 | -0.1120232 | -0.85539926 | -0.12616816 | 0.0607735 | 0.11577197 | 0.55198592 | -0.27044735 | -0.24078301 |
| **F2** | **Reykjavik** | **Stockholm** | **Sydney** | **Tallinn** | **Tokyo** | **Toronto** | **Vancouver** | **Vienna** | **Warsaw** | **Washington** | **Zürich** |
| **2005** | -0.41674306 | 0.78965863 | -0.11239248 | -0.87781199 | -0.02733 | 0.038599 | -0.04487 | 0.039269 | -0.6289 | 0.689309 | 0.480604 |
| **2006** | -0.41611683 | 0.785036 | -0.08181314 | -0.81733162 | -0.04055 | 0.006433 | -0.07947 | 0.162123 | -0.68476 | 0.653075 | 0.522802 |
| **2007** | -0.45442979 | 0.84535985 | -0.01052895 | -0.80122133 | -0.10354 | -0.05092 | -0.12221 | 0.276313 | -0.70709 | 0.632334 | 0.547868 |
| **2008** | -0.45515707 | 0.79883368 | 0.0315141 | -0.7569911 | -0.1198 | -0.06891 | -0.1408 | 0.279533 | -0.66908 | 0.649312 | 0.559967 |
| **2009** | -0.46504641 | 0.72600103 | 0.0093318 | -0.78679964 | -0.13689 | -0.05754 | -0.12624 | 0.309519 | -0.60582 | 0.6877 | 0.577638 |
| **2010** | -0.55151882 | 0.62052739 | 0.05843883 | -0.83984096 | -0.12248 | -0.05551 | -0.11717 | 0.370577 | -0.5569 | 0.557227 | 0.543177 |
| **2011** | -0.55180639 | 0.61591558 | 0.04602113 | -0.7785126 | -0.11298 | -0.11202 | -0.17798 | 0.35617 | -0.54073 | 0.540395 | 0.571849 |
| **2012** | -0.58176003 | 0.57808047 | 0.03808128 | -0.78330851 | -0.13843 | -0.19013 | -0.25292 | 0.364114 | -0.58846 | 0.501607 | 0.605492 |
| **2013** | -0.64230428 | 0.53096553 | -0.01386778 | -0.80947895 | -0.06013 | -0.23359 | -0.28625 | 0.432161 | -0.54355 | 0.482529 | 0.592796 |
| **2014** | -0.61856409 | 0.44643023 | -0.02132011 | -0.81064216 | 0.051632 | -0.23296 | -0.29076 | 0.434777 | -0.45328 | 0.464415 | 0.558779 |
| **2015** | -0.57980041 | 0.51668911 | -0.0201793 | -0.79422848 | 0.010568 | -0.22535 | -0.26205 | 0.431656 | -0.44996 | 0.45694 | 0.524632 |
| **2016** | -0.56307988 | 0.525219 | -0.01832684 | -0.75106385 | -0.00093 | -0.20999 | -0.233 | 0.427795 | -0.45718 | 0.423687 | 0.53662 |
| **2017** | -0.55647071 | 0.52049146 | -0.04724337 | -0.81525273 | -0.0348 | -0.14623 | -0.1605 | 0.394444 | -0.48424 | 0.448309 | 0.575232 |
| **2018** | -0.60199524 | 0.52426055 | -0.06624823 | -0.64931891 | -0.0278 | -0.14492 | -0.15372 | 0.324473 | -0.45566 | 0.470389 | 0.600441 |
| **2019** | -0.53470611 | 0.52274112 | -0.09165011 | -0.50035366 | -0.04283 | -0.13366 | -0.13109 | 0.253199 | -0.44379 | 0.475608 | 0.646533 |

**Table B.3:** Dynamic scores of urban smartness with respect to the third principal component of DFA on the drivers of smart cities, 2005-2019.

| F3 | Amsterdam | Barcelona | Berlin | Bratislava | Brisbane | Brussels | Copenhagen | Dublin | Frankfurt | Helsinki | London |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | -0.11898 | -0.01643 | 0.337482 | 0.173572 | -0.28961 | -0.00433 | -0.09877 | 0.096228 | 1.443749 | -0.05778 | -0.3437 |
| 2006 | -0.09989 | -0.08487 | 0.348649 | 0.181245 | -0.28175 | 0.010992 | -0.12781 | 0.100324 | 1.454311 | -0.03661 | -0.26135 |
| 2007 | -0.08223 | -0.16914 | 0.394905 | 0.210972 | -0.29566 | 0.041001 | -0.16263 | 0.064006 | 1.511168 | 0.001306 | -0.19841 |
| 2008 | -0.0647 | -0.20065 | 0.400162 | 0.200657 | -0.26963 | 0.06377 | -0.15414 | 0.062181 | 1.477163 | 0.007621 | -0.12249 |
| 2009 | -0.06468 | -0.26634 | 0.357483 | 0.2044 | -0.25489 | -0.00189 | -0.11593 | 0.036329 | 1.406298 | -0.03875 | -0.15666 |
| 2010 | -0.08711 | -0.28626 | 0.287248 | 0.254181 | -0.2648 | -0.05498 | -0.08579 | 0.012185 | 1.342906 | -0.02842 | -0.19565 |
| 2011 | -0.07479 | -0.23778 | 0.220305 | 0.274349 | -0.25697 | -0.04997 | -0.0364 | 0.023027 | 1.279578 | -0.05761 | -0.17825 |
| 2012 | -0.0522 | -0.17296 | 0.212671 | 0.278983 | -0.24882 | -0.03006 | -0.07502 | 0.027465 | 1.242201 | -0.06413 | -0.13077 |
| 2013 | -0.07605 | -0.20983 | 0.233378 | 0.29408 | -0.27572 | -0.04653 | -0.00521 | 0.042269 | 1.229544 | -0.04727 | -0.16589 |
| 2014 | -0.10953 | -0.22051 | 0.266013 | 0.230603 | -0.2919 | -0.00627 | 0.106059 | -0.01375 | 1.250579 | -0.05365 | -0.19956 |
| 2015 | -0.08907 | -0.20667 | 0.251543 | 0.286429 | -0.29265 | -0.01403 | 0.062511 | 0.012729 | 1.226912 | -0.08379 | -0.21617 |
| 2016 | -0.06868 | -0.19958 | 0.25554 | 0.300049 | -0.29399 | -0.0082 | 0.020095 | 0.061483 | 1.227956 | -0.11505 | -0.20464 |
| 2017 | -0.05402 | -0.19448 | 0.244052 | 0.293898 | -0.26311 | 0.001649 | 0.003566 | 0.037981 | 1.241449 | -0.1443 | -0.13557 |
| 2018 | -0.04029 | -0.19999 | 0.242788 | 0.270746 | -0.25031 | 0.003352 | -0.03213 | -0.02332 | 1.203507 | -0.12261 | -0.09779 |
| 2019 | -0.00745 | -0.20994 | 0.231366 | 0.230465 | -0.23134 | 0.029228 | -0.06267 | -0.0543 | 1.181138 | -0.09723 | -0.0955 |

| F3 | Los Angeles | Madrid | Manchester | Melbourne | Milan | Montreal | Munich | New York | Oslo | Paris | Prague |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | -0.11854 | -0.0391 | -0.1237 | -0.37375 | 0.134912 | -0.41384 | 0.915722 | -0.24838 | 0.022256 | -0.01184 | 0.343711 |
| 2006 | -0.12552 | -0.09465 | -0.05257 | -0.36931 | 0.225209 | -0.39593 | 0.92275 | -0.26064 | -0.01188 | -0.09191 | 0.298874 |
| 2007 | -0.13713 | -0.16493 | 0.010071 | -0.38083 | 0.293604 | -0.38213 | 0.970392 | -0.27488 | -0.073 | -0.16482 | 0.298522 |
| 2008 | -0.11927 | -0.18446 | 0.061357 | -0.3493 | 0.245947 | -0.37175 | 0.960281 | -0.25324 | -0.05665 | -0.26706 | 0.243664 |
| 2009 | -0.06638 | -0.23848 | 0.015278 | -0.33907 | 0.234325 | -0.37479 | 0.904073 | -0.19306 | -0.04028 | -0.22841 | 0.256488 |
| 2010 | -0.03829 | -0.2518 | -0.0318 | -0.35337 | 0.256547 | -0.39805 | 0.835909 | -0.16435 | -0.01314 | -0.13986 | 0.299386 |
| 2011 | -0.03254 | -0.20896 | -0.02263 | -0.34807 | 0.234386 | -0.35549 | 0.766339 | -0.16452 | -0.00801 | -0.18819 | 0.234364 |
| 2012 | -0.04672 | -0.15789 | 0.016838 | -0.33143 | 0.198989 | -0.32452 | 0.74877 | -0.18339 | -0.03372 | -0.23689 | 0.208024 |
| 2013 | -0.00243 | -0.19168 | -0.01744 | -0.36697 | 0.14353 | -0.31857 | 0.754897 | -0.14807 | -0.00462 | -0.29847 | 0.246782 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2014** | 0.029043 | -0.2008 | -0.05505 | -0.37854 | 0.105437 | -0.30992 | 0.785743 | -0.11839 | -0.01387 | -0.27768 | 0.231673 |
| **2015** | 0.057824 | -0.19571 | -0.05883 | -0.38509 | 0.09268 | -0.28891 | 0.762844 | -0.09588 | -0.01349 | -0.25944 | 0.195125 |
| **2016** | 0.074614 | -0.19571 | -0.02657 | -0.38774 | 0.069049 | -0.27092 | 0.762822 | -0.08475 | 0.005712 | -0.24255 | 0.152226 |
| **2017** | 0.052265 | -0.18761 | 0.032896 | -0.36021 | 0.065766 | -0.24726 | 0.744235 | -0.10785 | -0.02062 | -0.25395 | 0.157522 |
| **2018** | 0.045387 | -0.18895 | 0.077402 | -0.34659 | 0.041164 | -0.21374 | 0.731247 | -0.11783 | -0.02779 | -0.26931 | 0.13628 |
| **2019** | 0.058523 | -0.20187 | 0.086991 | -0.33058 | -0.01258 | -0.20785 | 0.71078 | -0.11192 | -0.04245 | -0.26246 | 0.097652 |
| **F3** | **Reykjavik** | **Stockholm** | **Sydney** | **Tallinn** | **Tokyo** | **Toronto** | **Vancouver** | **Vienna** | **Warsaw** | **Washington** | **Zürich** |
| **2005** | -0.22246 | -0.17679 | -0.39215 | -0.21742 | -0.13155 | -0.40555 | -0.34149 | -0.00493 | 0.409917 | 0.170871 | 0.102687 |
| **2006** | -0.203 | -0.17688 | -0.38552 | -0.25556 | -0.18965 | -0.39222 | -0.32399 | -0.00035 | 0.423446 | 0.16778 | 0.08827 |
| **2007** | -0.21016 | -0.22771 | -0.39984 | -0.24338 | -0.18812 | -0.37794 | -0.30752 | 0.003985 | 0.412312 | 0.141694 | 0.086543 |
| **2008** | -0.17788 | -0.2301 | -0.36069 | -0.28209 | -0.19407 | -0.36823 | -0.30014 | -0.00017 | 0.393511 | 0.148142 | 0.062281 |
| **2009** | -0.14447 | -0.18636 | -0.35122 | -0.22333 | -0.19182 | -0.37156 | -0.30177 | 0.046971 | 0.3848 | 0.203675 | 0.100003 |
| **2010** | -0.12143 | -0.08315 | -0.3655 | -0.1755 | -0.19633 | -0.39681 | -0.32522 | 0.026557 | 0.377309 | 0.226131 | 0.139242 |
| **2011** | -0.1131 | -0.09893 | -0.35879 | -0.17143 | -0.17555 | -0.35704 | -0.28632 | 0.039412 | 0.373965 | 0.223042 | 0.11258 |
| **2012** | -0.11162 | -0.12778 | -0.35 | -0.13722 | -0.16293 | -0.32222 | -0.25394 | 0.023558 | 0.312759 | 0.211229 | 0.072737 |
| **2013** | -0.13126 | -0.05043 | -0.37713 | -0.11757 | -0.22515 | -0.32082 | -0.24864 | 0.026656 | 0.297099 | 0.255473 | 0.122045 |
| **2014** | -0.13318 | -0.00325 | -0.38653 | -0.13482 | -0.29715 | -0.31211 | -0.24306 | 0.047765 | 0.268537 | 0.272151 | 0.165934 |
| **2015** | -0.11922 | 0.002279 | -0.39353 | -0.12936 | -0.28976 | -0.28772 | -0.21615 | 0.050592 | 0.210265 | 0.294877 | 0.128833 |
| **2016** | -0.10896 | 0.001672 | -0.3986 | -0.1376 | -0.28743 | -0.26541 | -0.19307 | -0.00521 | 0.148974 | 0.310982 | 0.103475 |
| **2017** | -0.11662 | -0.02546 | -0.37363 | -0.19771 | -0.27027 | -0.24164 | -0.16666 | 0.026463 | 0.128233 | 0.28646 | 0.044541 |
| **2018** | -0.13389 | -0.03287 | -0.35396 | -0.14246 | -0.28746 | -0.20977 | -0.12858 | 0.034646 | 0.112345 | 0.289497 | 0.031293 |
| **2019** | -0.06391 | -0.03895 | -0.33161 | -0.09279 | -0.28726 | -0.20053 | -0.118 | 0.029349 | 0.104767 | 0.317679 | -0.01677 |

# compAPPENDIX C

**Results of PVAR Model -2-:**

**Table C.1:** Westerlund test for cointegration, 2009-2019.

| | | |
|---|---|---|
| Ho: No cointegration | Number of panels = 26 | |
| Ha: Some panels are cointegrated | Number of periods= 15 | |
| **Variance ratio** | **Statistic** | **p-value** |
| | -0.3325 | 0.3697 |

**Table C.2:** Lag selection, 2009-2019.

| Lag | CD | J | J pvalue | MBIC | MAIC | MQIC |
|---|---|---|---|---|---|---|
| **1** | 1 | 159.4553 | .1790512 | -641.2829 | -128.5447 | -334.6723 |
| **2** | 1 | 112.9537 | .3529958 | -487.6 | -103.0463 | -257.642 |
| **3** | 1 | 64.04901 | .7364879 | -336.3201 | -79.95099 | -183.0148 |
| **4** | 1 | 40.3233 | .2849003 | -159.8612 | -31.6767 | -83.20859 |

**Table C.3:** Stability test of PVAR model, 2009-2019.

| **Eigenvalue** | | **Modulus** |
|---|---|---|
| Real | Imaginary | |
| 0.921457 | 0 | 0.921457 |
| 0.717978 | -0.0746 | 0.721843 |
| 0.717978 | 0.074598 | 0.721843 |
| -0.35928 | 0 | 0.35928 |
| 0.290782 | 0 | 0.290782 |
| 0.191407 | 0 | 0.191407 |

**Table C.4:** PVAR (1 lag) model, 2009-2019.

| | Coef. | Std. Err. | z | P>z | [95% Conf. | |
|---|---|---|---|---|---|---|
| **CO2** | | | | | | |
| **CO2 L1.** | -0.2951* | 0.061518 | -4.8 | 0 | -0.41568 | -0.17453 |
| **Technology L1.** | -0.83547* | 0.17461 | -4.78 | 0 | -1.1777 | -0.49324 |
| **Governance L1.** | -1.29595* | 0.312438 | -4.15 | 0 | -1.90832 | -0.68358 |
| **Community L1.** | -0.49502* | 0.103054 | -4.8 | 0 | -0.697 | -0.29303 |
| **Economy L1.** | 2.602926* | 0.298695 | 8.71 | 0 | 2.017494 | 3.188357 |
| **PopDensity L1.** | -0.00443 | 0.003054 | -1.45 | 0.147 | -0.01042 | 0.001553 |
| **Technology** | | | | | | |
| **CO2 L1.** | -0.04907* | 0.012481 | -3.93 | 0 | -0.07354 | -0.02461 |
| **Technology L1.** | 0.806201* | 0.062869 | 12.82 | 0 | 0.682981 | 0.929422 |
| **Governance L1.** | -0.32432* | 0.110966 | -2.92 | 0.003 | -0.54181 | -0.10683 |
| **Community L1.** | -0.04267* | 0.015769 | -2.71 | 0.007 | -0.07357 | -0.01176 |
| **Economy L1.** | 0.501063* | 0.058041 | 8.63 | 0 | 0.387304 | 0.614822 |
| **PopDensity L1.** | 0.000135 | 0.000621 | 0.22 | 0.828 | -0.00108 | 0.001353 |
| **Governance** | | | | | | |
| **CO2 L1.** | -0.01031 | 0.008401 | -1.23 | 0.22 | -0.02678 | 0.006152 |
| **Technology L1.** | 0.065442* | 0.025942 | 2.52 | 0.012 | 0.014597 | 0.116287 |
| **Governance L1.** | 0.424169* | 0.079194 | 5.36 | 0 | 0.268953 | 0.579386 |
| **Community L1.** | 0.014039 | 0.010375 | 1.35 | 0.176 | -0.0063 | 0.034374 |
| **Economy L1.** | 0.08811* | 0.019651 | 4.48 | 0 | 0.049595 | 0.126624 |
| **PopDensity L1.** | 0.000836* | 0.000281 | 2.97 | 0.003 | 0.000285 | 0.001388 |
| **Community** | | | | | | |
| **CO2 L1.** | -0.03164 | 0.031605 | -1 | 0.317 | -0.09358 | 0.030308 |
| **Technology L1.** | 0.160955*** | 0.093876 | 1.71 | 0.086 | -0.02304 | 0.344948 |
| **Governance L1.** | 0.452441* | 0.146973 | 3.08 | 0.002 | 0.164379 | 0.740503 |
| **Community L1.** | 0.231386* | 0.079849 | 2.9 | 0.004 | 0.074884 | 0.387887 |
| **Economy L1.** | 1.105347* | 0.169489 | 6.52 | 0 | 0.773155 | 1.437538 |
| **PopDensity L1.** | 0.000444 | 0.000761 | 0.58 | 0.56 | -0.00105 | 0.001936 |
| **Economy** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **CO2 L1.** | 0.008272 | 0.009325 | 0.89 | 0.375 | -0.01 | 0.026548 |
| **Technology L1.** | -0.04917*** | 0.029678 | -1.66 | 0.098 | -0.10734 | 0.008994 |
| **Governance L1.** | 0.103037** | 0.046371 | 2.22 | 0.026 | 0.012151 | 0.193922 |
| **Community L1.** | 0.029542** | 0.013084 | 2.26 | 0.024 | 0.003898 | 0.055187 |
| **Economy L1.** | 0.81148* | 0.108747 | 7.46 | 0 | 0.59834 | 1.024619 |
| **PopDensity L1.** | 2.41E-05 | 0.000336 | 0.07 | 0.943 | -0.00063 | 0.000683 |
| **PopDensity** | | | | | | |
| **CO2 L1.** | 8.306387* | 2.13493 | 3.89 | 0 | 4.122002 | 12.49077 |
| **Technology L1.** | -7.63133 | 5.624058 | -1.36 | 0.175 | -18.6543 | 3.391624 |
| **Governance L1.** | 74.45383* | 14.28241 | 5.21 | 0 | 46.46081 | 102.4468 |
| **Community L1.** | 14.59211* | 2.885716 | 5.06 | 0 | 8.936207 | 20.24801 |
| **Economy L1.** | 50.36439* | 6.885414 | 7.31 | 0 | 36.86923 | 63.85956 |
| **PopDensity L1.** | 0.502189* | 0.10138 | 4.95 | 0 | 0.303489 | 0.70089 |

Instruments : l(1/4).(CO2 Technology Governance Community Economy PopDensity).
Control variable: Population density.
Hansen's J chi2(108) = 113.03776 (p = 0.351)

**Table C.5:** PVAR Granger causality, 2009-2019.

| **Equation \ Excluded** | **chi2** | **df** | **Prob > chi2** |
|---|---|---|---|
| **CO2** | | | |
| Technology | 22.894* | 1 | 0 |
| Governance | 17.205* | 1 | 0 |
| Community | 23.073* | 1 | 0 |
| Economy | 75.939 * | 1 | 0 |
| PopDensity | 2.106 | 1 | 0.147 |
| ALL | 136.41* | 5 | 0 |
| **Technology** | | | |
| CO2 | 15.459* | 1 | 0 |
| Governance | 8.542* | 1 | 0.003 |
| Community | 7.322* | 1 | 0.007 |
| Economy | 74.526* | 1 | 0 |
| PopDensity | 0.047* | 1 | 0.828 |
| ALL | 106.024* | 5 | 0 |
| **Governance** | | | |
| CO2 | 1.507 | 1 | 0.22 |
| Technology | 6.364** | 1 | 0.012 |
| Community | 1.831 | 1 | 0.176 |
| Economy | 20.104 * | 1 | 0 |

| | | | |
|---|---|---|---|
| PopDensity | 8.832* | 1 | 0.003 |
| ALL | 39.422* | 5 | 0 |
| **Community** | | | |
| CO2 | 1.002 | 1 | 0.317 |
| Technology | 2.94*** | 1 | 0.086 |
| Governance | 9.477* | 1 | 0.002 |
| Economy | 42.532* | 1 | 0 |
| PopDensity | 0.34 | 1 | 0.56 |
| ALL | 72.772* | 5 | 0 |
| **Economy** | | | |
| CO2 | 0.787 | 1 | 0.37 |
| Technology | 2.745*** | 1 | 0.098 |
| Governance | 4.937** | 1 | 0.026 |
| Community | 5.098** | 1 | 0.024 |
| PopDensity | 0.005 | 1 | 0.943 |
| ALL | 11.164** | 5 | 0.048 |
| **PopDensity** | | | |
| CO2 | 15.138* | 1 | 0 |
| Technology | 1.841 | 1 | 0.175 |
| Governance | 27.175* | 1 | 0 |
| Community | 25.57* | 1 | 0 |
| Economy | 53.504* | 1 | 0 |
| ALL | 100.456* | 5 | 0 |

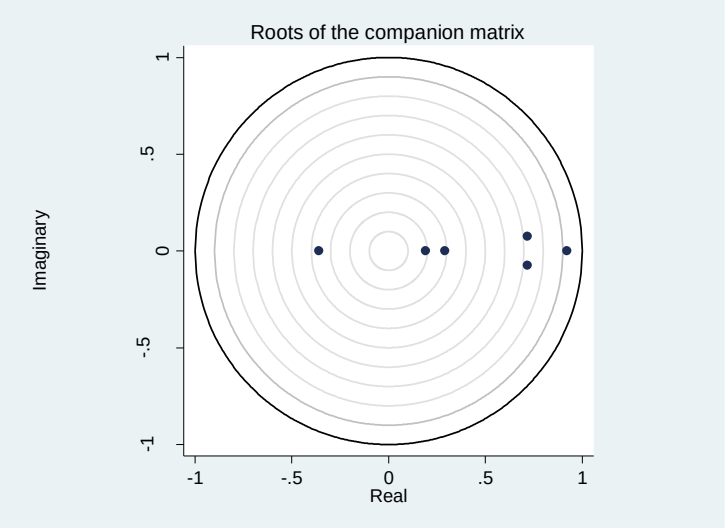



**Figure C.1:** Stability condition of PVAR model.

**Table C.6:** Variance decomposition, 2009-2019.

| CO2 | | CO2 | Technology | Governance | Community | Economy | PopDensity |
|---|---|---|---|---|---|---|---|
| | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 0.759488 | 0.065571 | 0.015028 | 0.038149 | 0.112303 | 0.009463 |
| | 10 | 0.710705 | 0.068956 | 0.014228 | 0.037242 | 0.159672 | 0.009197 |
| **Technology** | | | | | | | |
| | 1 | 0.144322 | 0.855678 | 0 | 0 | 0 | 0 |
| | 5 | 0.050367 | 0.56588 | 0.051143 | 0.0024 | 0.330088 | 0.000123 |
| | 10 | 0.036165 | 0.406458 | 0.038133 | 0.006718 | 0.512385 | 0.000141 |
| **Governance** | | | | | | | |
| | 1 | 0.012202 | 0.031987 | 0.955811 | 0 | 0 | 0 |
| | 5 | 0.012054 | 0.073971 | 0.662982 | 0.028625 | 0.192801 | 0.029568 |
| | 10 | 0.009405 | 0.052031 | 0.437654 | 0.036739 | 0.441295 | 0.022877 |
| **Community** | | | | | | | |
| | 1 | 0.104396 | 0.022927 | 0.006486 | 0.866192 | 0 | 0 |
| | 5 | 0.063731 | 0.031262 | 0.012713 | 0.551546 | 0.338125 | 0.002624 |
| | 10 | 0.047847 | 0.02359 | 0.015847 | 0.420077 | 0.489005 | 0.003635 |
| **Economy** | | | | | | | |
| | 1 | 0.000452 | 6.16E-09 | 0.00408 | 0.002514 | 0.992954 | 0 |
| | 5 | 0.001469 | 0.003429 | 0.0101 | 0.023579 | 0.960884 | 0.00054 |
| | 10 | 0.001467 | 0.00603 | 0.021173 | 0.032267 | 0.936981 | 0.002082 |
| **PopDens** | | | | | | | |
| | 1 | 0.116082 | 0.002241 | 0.08624 | 0.036311 | 0.015913 | 0.743215 |
| | 5 | 0.051024 | 0.002769 | 0.080644 | 0.102373 | 0.487196 | 0.275995 |
| | 10 | 0.030398 | 0.002193 | 0.070131 | 0.087533 | 0.646213 | 0.163533 |

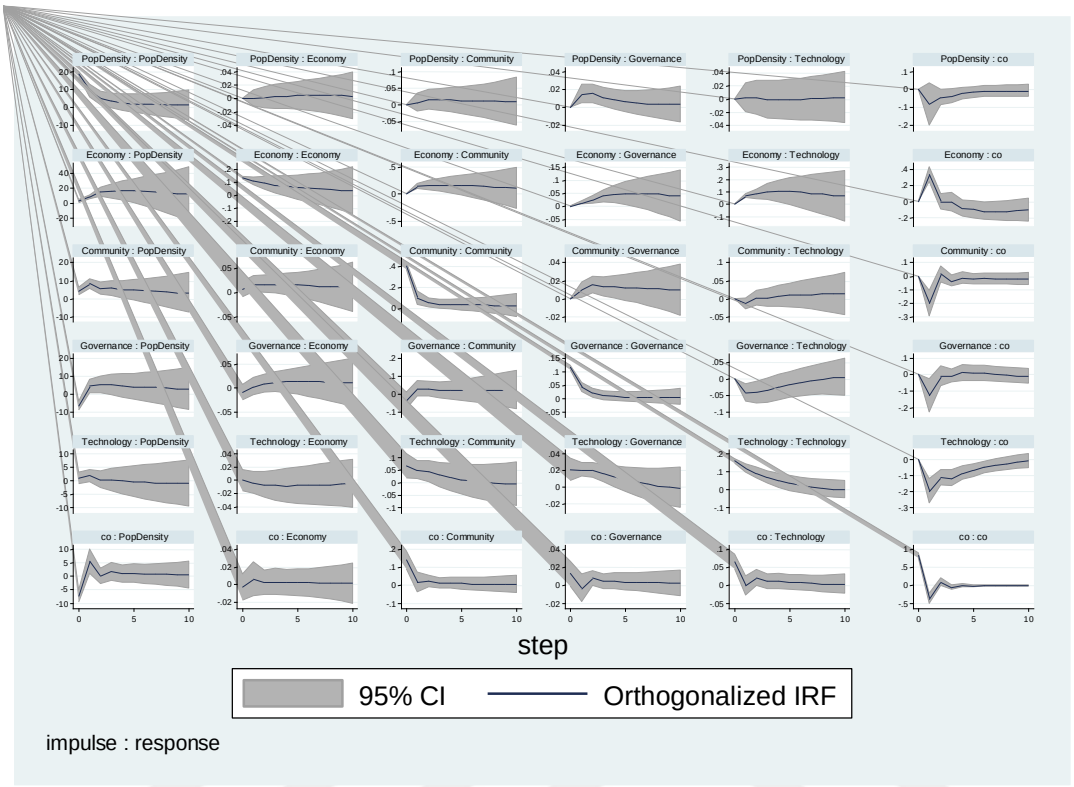



**Figure C.2:** Impulse response function, 2009-2019.

**Results of PVAR Model -3-:**

**Table C.7:** Westerlund test for cointegration, 2009-2019.

| | | |
|---|---|---|
| Ho: No cointegration | Number of panels= 26 | |
| Ha: Some panels are cointegrated | Number of periods= 15 | |
| **Variance ratio** | **Statistic** | **p-value** |
| | **-0.5857** | **0.2791** |

**Table C.8:** Lag selection, 2009-2019.

| lag | CD | J | J pvalue | MBIC | MAIC | MQIC |
|---|---|---|---|---|---|---|
| **1** | 0.999989 | 143.4913 | 0.49629 | -657.247 | -144.509 | -350.636 |
| **2** | 0.999993 | 94.60433 | 0.8176015 | -505.949 | -121.396 | -275.991 |
| **3** | 0.999996 | 69.78342 | 0.5520766 | -330.586 | -74.2166 | -177.28 |
| **4** | 0.999987 | 40.46662 | 0.2796208 | -159.718 | -31.5334 | -83.0653 |

**Table C.9:** Stability test of PVAR model, 2009-2019.

| **Eigenvalue** | | **Modulus** |
|---|---|---|
| Real | Imaginary | |
| 0.865687 | 0 | 0.865687 |
| 0.522068 | 0 | 0.522068 |
| 0.110159 | -0.40797 | 0.42258 |
| 0.110159 | 0.407969 | 0.42258 |
| -0.28801 | 0 | 0.288007 |
| 0.078836 | 0 | 0.078836 |

**Table C.10:** PVAR (1 lag) model, 2009-2019.

| | Coef. | Std. Err. | z | P>z | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| **Socialsus** | | | | | | |
| Socialsus L1. | 0.4738* | 0.03747 | 12.64 | 0 | 0.400353 | 0.547248 |
| Technology L1. | -0.03555* | 0.01436 | -2.48 | 0.013 | -0.0637 | -0.0074 |
| Governance L1 | 0.102969* | 0.019745 | 5.21 | 0 | 0.064269 | 0.141669 |
| Community L1. | 0.070465* | 0.008794 | 8.01 | 0 | 0.053229 | 0.0877 |
| Economy L1. | 0.139411* | 0.013652 | 10.21 | 0 | 0.112654 | 0.166168 |
| GDPGrowth L1. | 0.001805* | 0.000536 | 3.37 | 0.001 | 0.000756 | 0.002855 |
| **Technology** | | | | | | |
| Socialsus L1. | 0.56063* | 0.044371 | 12.64 | 0 | 0.473664 | 0.647595 |
| Technology L1. | 0.780054* | 0.025405 | 30.71 | 0 | 0.730262 | 0.829846 |
| Governance L1 | 0.351832* | 0.048972 | 7.18 | 0 | 0.255849 | 0.447816 |
| Community L1. | -0.17586* | 0.020722 | -8.49 | 0 | -0.21648 | -0.13525 |
| Economy L1. | -0.19431* | 0.034621 | -5.61 | 0 | -0.26216 | -0.12645 |
| GDPGrowth L1. | -0.00228* | 0.000895 | -2.55 | 0.011 | -0.00404 | -0.00053 |
| **Governance** | | | | | | |
| Socialsus L1. | 0.513277* | 0.043772 | 11.73 | 0 | 0.427486 | 0.599069 |
| Technology L1. | 0.096503* | 0.016922 | 5.7 | 0 | 0.063336 | 0.12967 |
| Governance L1 | 0.294158* | 0.031666 | 9.29 | 0 | 0.232094 | 0.356223 |
| Community L1. | -0.0146** | 0.007755 | -1.88 | 0.06 | -0.0298 | 0.000601 |
| Economy L1. | 0.087109* | 0.015789 | 5.52 | 0 | 0.056164 | 0.118055 |
| GDPGrowth L1. | 0.002115* | 0.00071 | 2.98 | 0.003 | 0.000724 | 0.003507 |
| **Community** | | | | | | |
| Socialsus L1. | -0.04919 | 0.104204 | -0.47 | 0.637 | -0.25342 | 0.155048 |
| Technology L1. | 1.025529* | 0.055803 | 18.38 | 0 | 0.916158 | 1.1349 |
| Governance L1 | 0.484698* | 0.072266 | 6.71 | 0 | 0.343059 | 0.626337 |
| Community L1. | -0.24048* | 0.023353 | -10.3 | 0 | -0.28625 | -0.19471 |
| Economy L1. | -0.6482* | 0.068679 | -9.44 | 0 | -0.78281 | -0.51359 |
| GDPGrowth L1. | 0.009541* | 0.00334 | 2.86 | 0.004 | 0.002995 | 0.016087 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Economy** | | | | | | |
| Socialsus L1. | 0.482322* | 0.058872 | 8.19 | 0 | 0.366935 | 0.597709 |
| Technology L1. | -0.02629 | 0.017126 | -1.54 | 0.125 | -0.05986 | 0.007277 |
| Governance L1 | -0.32637* | 0.041823 | -7.8 | 0 | -0.40834 | -0.24439 |
| Community L1. | 0.06519* | 0.009384 | 6.95 | 0 | 0.046798 | 0.083581 |
| Economy L1. | 0.307928* | 0.050166 | 6.14 | 0 | 0.209603 | 0.406252 |
| GDPGrowth L1. | 0.002922* | 0.000761 | 3.84 | 0 | 0.001431 | 0.004414 |
| **GDPGrowth** | | | | | | |
| Socialsus L1. | -34.0227* | 4.568407 | -7.45 | 0 | -42.9766 | -25.0688 |
| Technology L1. | -3.28755*** | 1.987676 | -1.65 | 0.098 | -7.18332 | 0.608227 |
| Governance L1 | 65.34627* | 6.764639 | 9.66 | 0 | 52.08782 | 78.60471 |
| Community L1. | -6.27477* | 0.902288 | -6.95 | 0 | -8.04322 | -4.50632 |
| Economy L1. | -20.6544* | 2.732717 | -7.56 | 0 | -26.0105 | -15.2984 |
| GDPGrowth L1. | -0.21656* | 0.081072 | -2.67 | 0.008 | -0.37546 | -0.05766 |

Instruments: l(1/6)( Socialsus Technology Governance Community Economy GDPGrowth).
Hansen's J chi2(180) = 183.38158 (p = 0.416). Control variable: GDP growth.

**Table C.11:** PVAR Granger causality, 2009-2019

| Equation \ Excluded | chi2 | df | Prob > chi2 |
|---|---|---|---|
| **Socialsus** | | | |
| Technology | 6.126* | 1 | 0.013 |
| Governance | 27.195* | 1 | 0 |
| Community | 64.21* | 1 | 0 |
| Economy | 104.284* | 1 | 0 |
| GDPGrowth | 11.364* | 1 | 0.001 |
| **ALL** | 219.597* | 5 | 0 |
| **Technology** | | | |
| Socialsus | 159.644* | 1 | 0 |
| Governance | 51.615* | 1 | 0 |
| Community | 72.021* | 1 | 0 |
| Economy | 31.499* | 1 | 0 |
| GDPGrowth | 6.513* | 1 | 0.011 |
| **ALL** | 251.584* | 5 | 0 |
| **Governance** | | | |
| Socialsus | 137.502* | 1 | 0 |
| Technology | 32.521* | 1 | 0 |
| Community | 3.544** | 1 | 0.06 |
| Economy | 30.439* | 1 | 0 |

| | | | |
|---|---|---|---|
| GDPGrowth | 8.878* | 1 | 0.003 |
| **ALL** | 237.738* | 5 | 0 |
| **Community** | | | |
| Socialsus | 0.223 | 1 | 0.637 |
| Technology | 337.742* | 1 | 0 |
| Governance | 44.986* | 1 | 0 |
| Economy | 89.078* | 1 | 0 |
| GDPGrowth | 8.161* | 1 | 0.004 |
| **ALL** | 486.261* | 5 | 0 |
| **Economy** | | | |
| Socialsus | 67.121* | 1 | 0 |
| Technology | 2.356 | 1 | 0.125 |
| Governance | 60.893* | 1 | 0 |
| Community | 48.264* | 1 | 0 |
| GDPGrowth | 14.744* | 1 | 0 |
| **ALL** | 143.371* | 5 | 0 |
| **GDPGrowth** | | | |
| Socialsus | 55.464* | 1 | 0 |
| Technology | 2.736*** | 1 | 0.098 |
| Governance | 93.315* | 1 | 0 |
| Community | 48.362* | 1 | 0 |
| Economy | 57.126* | 1 | 0 |
| **ALL** | 181.692* | 5 | 0 |

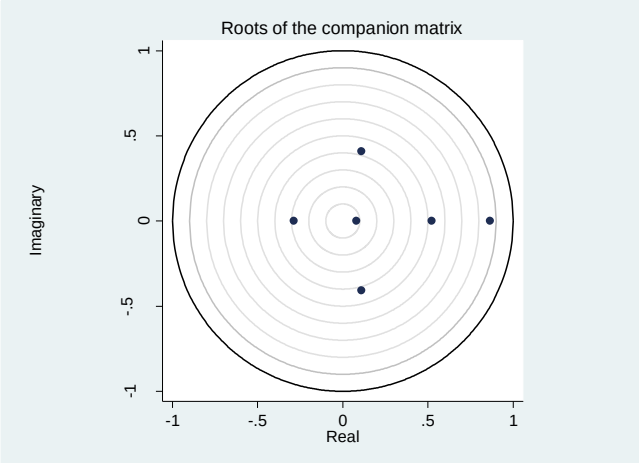



**Figure C.3:** Stability condition of PVAR model.

**Table C.12:** Variance decomposition, 2009-2019.

| Response variable and forecast horizon | Impulse Variable | | | | | |
|---|---|---|---|---|---|---|
| | **Socialsus** | **Technology** | **Governance** | **Community** | **Economy** | **GDPGrowth** |
| **Social sus** | | | | | | |
| **1** | 1 | 0 | 0 | 0 | 0 | 0 |
| **5** | 0.769783 | 0.024297 | 0.057573 | 0.098923 | 0.019316 | 0.030108 |
| **10** | 0.74894 | 0.030798 | 0.074792 | 0.094218 | 0.019812 | 0.031441 |
| **Technology** | | | | | | |
| **1** | 0.050639 | 0.949361 | 0 | 0 | 0 | 0 |
| **5** | 0.179835 | 0.572633 | 0.087933 | 0.132459 | 0.016673 | 0.010467 |
| **10** | 0.208549 | 0.524023 | 0.11968 | 0.116049 | 0.017351 | 0.014348 |
| **Governance** | | | | | | |
| **1** | 0.152537 | 0.029421 | 0.818042 | 0 | 0 | 0 |
| **5** | 0.217426 | 0.046235 | 0.706093 | 0.004306 | 0.007896 | 0.018045 |
| **10** | 0.228643 | 0.053088 | 0.68416 | 0.004704 | 0.008988 | 0.020418 |
| **Community** | | | | | | |
| **1** | 0.079859 | 0.10906 | 0.0006 | 0.810482 | 0 | 0 |
| **5** | 0.087738 | 0.155663 | 0.087425 | 0.616493 | 0.031979 | 0.020702 |
| **6** | 0.091018 | 0.156811 | 0.088292 | 0.610954 | 0.031898 | 0.021028 |
| **10** | 0.096263 | 0.157156 | 0.093419 | 0.600072 | 0.031691 | 0.021398 |
| **Economy** | | | | | | |
| **1** | 0.048768 | 0.014607 | 0.055033 | 0.047889 | 0.833704 | 0 |
| **5** | 0.127228 | 0.031369 | 0.121472 | 0.071193 | 0.630198 | 0.018542 |
| **10** | 0.128295 | 0.031708 | 0.122322 | 0.070996 | 0.628004 | 0.018675 |
| **GDPGrowth** | | | | | | |
| **1** | 0.053647 | 0.181648 | 0.31138 | 0.050768 | 0.016216 | 0.386341 |
| **5** | 0.14246 | 0.1443 | 0.421518 | 0.059217 | 0.030037 | 0.202468 |
| **10** | 0.142549 | 0.144181 | 0.421814 | 0.059159 | 0.030014 | 0.202284 |

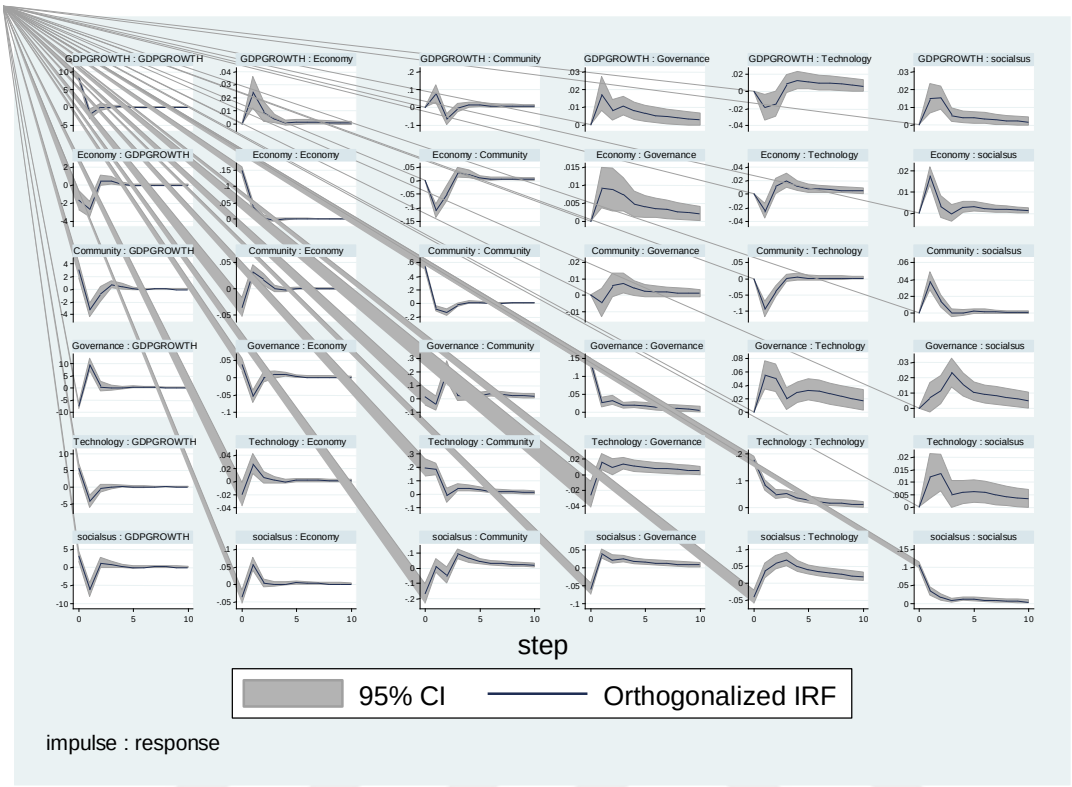



**Figure C.4:** Impulse response function, 2009-2019.

# CURRICULUM VITAE

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