ABSTRACT

A Dynamic Approach to Examine the Growth Trajectory of
e-Participation Factors

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This research explores key factors that drive e-participation growth among 147 nation-states over seven years (2014-2020). While the literature utilizing information and communication technologies (ICT) to advance e-participation research has proliferated in recent years, these studies generally do not clarify how e-participation growth occurs and how it is sustained. The current study develops an e-participation model based on Stigmergy Theory to identify core factors that drive e-participation. Then, Latent Growth Curve Modeling (LGM) is used to examine differences in countries' growth trajectories over time. This study contributes to understanding the factors that expand and sustain e-participation to reduce developing countries' learning curves.

A Dynamic Approach to Examine the Growth Trajectory of e-Participation Factors

by

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DEDICATION

To the love of my life, Mary Kate. Your support, encouragement, and sacrifice have sustained me throughout this dissertation. This work is dedicated to my son Joseph Zane. You have made me stronger, better and you add joy to my life more than I could have ever imagined. I love you to the moon and back.

CHAPTER ONE

Introduction

Citizen participation is a practice that expresses the human endeavor to influence the governance of communities. With the rapid advancement of Information Communication Technology (ICT), such as social media and the Internet, avenues for citizen participation now include the digital realm under the umbrella of "e-participation". Nonetheless, citizens remain relatively inactive, or at least insignificantly engaged in any form of participation (offline or online), and oblivious to such practice's societal importance. For example, only 49.1% of the world's citizens use the Internet to interact with public authorities and take advantage of e-government services[1]. e-Participation is an elevated type of engagement. It exists outside the common hurdles of everyday life where the effects of participation are often invisible or take time to materialize (Hassan and Hamari 2019).

e-Participation is described as the use of ICT to support democratic-based decisions (Macintosh 2004); (Medaglia 2012). e-Participation refers to citizens' direct involvement in the control, decision-making, and support of governmental directives through the use of ICT. Thus, e-participation extends and transforms citizen engagement in democratic and consultative processes. It also facilitates opportunities for dialogue between governments and citizens using ICT tools (Medaglia 2012) and aims to increase

[1] OECD (2019). Government at a Glance 2019. Paris: OECD Publishing. Retrieved November 17, 2019, from https://doi.org/10.1787/8ccf5c38-en

the access and availability of governmental information. Overall, the objective of e-participation is to promote a fair, efficient society, and government.

Governments support and promote e-participation for various reasons, such as to improve the efficiency, acceptance, and legitimacy of political processes (Macintosh et al. 2009). e-Participation initiatives are deployed to achieve four general objectives of citizen participation: information exchange, education and support building, decision-making supplementation, and input probing (Phang and Kankanhalli 2008). Most forms of e-participation that are readily available, or in development, are supported by ICT. Examples include, but are not limited to, electronic voting systems (Macintosh 2004), group decision support systems (French et al. 2007), weblogs (blogs) (Al-Dalou and Abu-Shanab 2013), and chat technologies (Wimmer 2007). e-Participation tools are designed to encourage citizen engagement through hedonic design strategies that include social media or local government weblogs (blogs) (Alarabiat et al. 2017); (Bonsón et al. 2015); (Hofmann et al. 2013); (Mossberger et al. 2013).

The term e-participation has been coined to indicate the processes and structures through which ICT supports relationships among citizens, governments, and public organizations. The scope of e-participation is expanding to include the growing trend to involve citizens in political decision-making that is related to their government (Medaglia 2012). Yet, regardless of the changes in ICT to accommodate citizens, only a few e-participation initiatives have achieved their objectives (Phang and Kankanhalli 2008). For example, e-participation initiatives often fail to reach some crucial segments of the population, such as young people and the middle class (Barros and Sampaio 2016). To date, the success of e-participation varies among the citizenries.

The term 'participation' implies a reciprocal relationship between 2 parties or more, in which all contribute to a common goal. Participation is a goal-oriented activity. For example, a major league baseball team has a roster of 25 players in which all share one goal, 'WINNING' the game. Each player participates in a coordinated manner towards the goal. Team member participation means each player does his part to contribute to the objective. Hence, the participatory process is important for the activities and the team plan. Electronic participation in government activities is no different. Governments facilitate e-participation by developing ICT support, implementation strategies, and processes to encourage citizens to join the team and play a part. The processes to encourage e-participation involve a variety of individuals, including practitioners, citizens, and government officials involved in electronic public administration, service delivery, policy making, and decision-making. Hence, a multitude of factors and actors are involved in the success of e-participation.

Currently, governments all over the world promote citizens' e-participation (Kim and Lee 2012). Hence, they must be actively involved in establishing the necessary components, including the ICT infrastructure and rapid technological development (Lironi 2016). ICT infrastructure and tools are fundamental to e-participation, and governments must have large budgets to support e-participation. For example, The United States federal government budget for 2021 has set aside nearly 53.36 billion dollars for federal civilian ICT. The budget estimates for 2021 exclude the portion of the budget allocated to the Department of Defense, as well as other classified IT spending (whitehouse.gov 2020). Globally, IT is a central theme in all government service transformation roadmaps. The Australian government, for example, is in the race in terms

of transformation maturity and strategic agility using ICT. Their IT spending reached $6.2 billion by 2018 and grew 3% in 2019 (budget.gov.au 2019). Despite government spending and efforts on developing and utilizing new ICT for e-participation, there is little understanding of how citizens' e-participation evolves over time and the factors that contribute to changes in, and growth of, e-participation.

The term 'e-government' is linked to e-participation in the literature and its meaning has evolved in the information systems (IS) field. e-Government has been described as e-voting facilitating e-democracy (Srivastava and Teo 2009) and as the information dissemination phase in which governments catalog information for public use (Reddick 2005). Another example is from the United Arab Emirates (UAE). In 2019 the UAE was ranked one of the most visited countries in the world. The UAE's e-government site has more than 4,000 federal and local e-services on its portal. Their e-government program issued 2,382,111 electronic entry permits to the country in 2019 (UAE e-Government 2020). Regardless of how e-government is described and implemented, *e-participation* facilitates e-government. As e-government continues to develop, e-participation is key to its success. Hence, understanding the different factors contributing to the growth of citizens' e-participation is also important for the development of e-government. Currently, there is little understanding of the impact of citizen involvement in e-participation on their communities and on their government (Alarabiat et al. 2017); (Lean et al. 2009); (Zheng 2017).

Researchers, governments, and supranational organizations have been and remain interested in the role of citizen engagement in e-government (Carter and Bélanger 2005); (Fung 2006); (Irvin and Stansbury 2004); (Kim and Lee 2017); (Olphert and Damodaran

2007). This, in most cases, depends on the citizens' intention to use e-government services, which is linked to the use of ICT by the citizens and their trust in government. For example, in Karen and Jungwoo's (2001) seminal article, the citizens were already at the center of the maturity model they described for e-government, and citizens' higher expectations were driving the evolution of e-government (Layne and Lee 2001), likely because trust developed. What is worth mentioning in Layne and Lee's (2001) article is that e-participation is not the main focus; however, they advocate for the increased participation of citizens in democratic processes through ICT means (Layne and Lee 2001); (Simonofski et al. 2017).

Although e-government research has progressed in the IS field, the literature has left significant gaps in our understanding of how citizen engagement (or participation) is best motivated and how it is affected by changing social structures, in addition to understanding the implications for good governance (Irani et al. 2007). Also, despite the substantial body of knowledge regarding e-government, the question of why many countries are not facing the challenge of involving citizens in the government's decision-making processes is not addressed (Mahrer and Krimmer 2005). The present study is associated with e-government because e-participation is key in raising a country's competitiveness in a global economy (Srivastava and Teo 2008), yet little is understood about factors contributing to the growth trajectory of e-participation.

Over the last two decades, e-participation researchers applied effort expectancy models (Venkatesh et al. 2003) to understand the intention to use e-participation technologies and to examine perceived usefulness (Carter and Belanger 2004), attitude (Oni et al. 2017), trust in government (Bélanger and Carter 2008), and social influence on

the intention to be more involved in e-participation. Additionally, research that explores the prominent factors involved in the growth of e-participation over time is limited. This type of research is harder to conduct compared to perception-based, behavioral research that is focused on behavioral intentions and trust, or research examining the economic effects of e-participation.

The present study contributes to understanding the factors supporting e-participation, which has implications for e-government formation and evolution, and has mostly been limited to ICT infrastructure (Ekelin 2007). Furthermore, the core of information systems research is the information technology artifact (ITA) (Orlikowski and Iacono 2001), and the research community has been encouraged to deeply engage with the ITA (Matook and Brown 2017). Orlikowski & Iacono state: "IT artifacts are those bundles of material and cultural properties packaged in some socially recognizable form such as hardware and/or software"(Orlikowski and Iacono 2001)121. The ITA in this study is the combination of hardware and software, skills, and services that facilitate citizens' activity with their government.

The objective of this research is two-fold. First, the aim is to identify significant factors of citizens' e-participation by considering under-investigated variables related to countries' economic and technologic landscape. After identifying important e-participation factors, the goal is to understand how those factors contribute to the growth trajectory of e-participation over time. This research utilizes stigmergy theory to create a framework for the mechanisms of e-participation and the literature on citizen engagement to formulate a model to explore e-participation mechanisms. By examining the evolution

of e-participation over time, this study contributes to the knowledge of how governments can improve citizens' e-participation rates.

In this study, the following questions will be addressed:

- *What factors contribute to the growth trajectory of e-participation?*
- *How is the stigmergic mechanism involved in e-participation?*

Citizens' e-participation is an important topic for both academicians and researchers due to the fact that e-government is based on ICT and its use (Grönlund and Horan 2005). This study's overall objective is to evaluate the growth trajectory of e-participation over time in 147 countries (see Table A.1, in Appendix A) to identify the significant factors contributing to citizens' e-participation and sustained growth. This will contribute to the development of practice-based efforts of countries in the initial phases of e-participation or those not yet involved.

Chapter two presents a literature review of the foundational literature about e-participation and discusses how e-government processes influence e-participation. Moving forward, in chapter three, I present the stigmergy theory approach that I use to model the mechanisms of e-participation. Also, this section presents the hypotheses supported by the literature. Chapter four discusses the sources for this study's datasets and their importance to enhance our understanding of countries' e-participation growth trajectory. Chapter five explains the chosen method for this study. Chapter six presents the quantitative findings, chapter seven discusses the findings and limitations, and chapter eight presents the summary.

CHAPTER TWO

Literature Review

To review the background literature for this study, I divided the relevant literature into two sections based on their academic research focus. In the first section, I examine how e-participation has been studied from the two perspectives of business and public administration. Following that, I review the literature on e-participation from the perspective of the IS discipline.

e-Participation in the Business and Public Administration Literature

In the business and public administration literature, e-participation's body of research shows a diversity of focus. For example, some research consists of case studies that focus on factors influencing the level of e-participation (Al-Quraan and Abu-Shanab 2015), citizens' objectives in using e-participation (Alrashedi et al. 2015), and e-participation adoption in e-government services (Belanche et al. 2012). This growing body of literature on e-participation supports the topic's interdisciplinary nature with contributions from public administration (Medaglia 2012; Zolotov et al. 2018), and business research (Avgerou and Bonina 2020; Carter and Bélanger 2005; Olphert and Damodaran 2007).

Contributions from both research areas show that e-participation activities and contextual factors have shifted in time towards analytical categories of research, and that the field has a high level of dynamism. The following paragraphs discuss three points

about the background of e-participation, including 1) the definition, 2) how ICT leverages e-participation development, and 3) the focus of prior research.

The Definition of e-Participation

In 1995, Verba, Scholzman, and Brady defined e-participation as "any voluntary action by citizens that are more or less directly aimed at influencing the management of collective affairs and public decision-making" (Verba et al. 1995, 98). These researchers state an important aspect of e-participation, which is a *voluntary* participatory activity that emphasizes citizen engagement. Table 2.1 shows the e-participation definitions from prior literature and how the definition has evolved over time.

Table 2.1: e-Participation Definitions in Literature

Citation	e-Participation Definitions	Definition Changes
(Verba et al. 1995, 98)	e-Participation as "any voluntary action by citizens that is more or less directly aimed at influencing the management of collective affairs and public decision-making"	
(Macintosh 2004)	e-Participation is related to the issues of enabling opportunities for consultation and dialogue between government and citizens by using a range of ICT tools.	Enabling dialogue with ICT tools
(Sæbø et al. 2008, 400)	"e-Participation involves the extension and transformation of participation in societal democratic and consultative processes mediated by information and communication technologies (ICT), primarily the Internet ."	ICT and Internet mediation for society involvement in democratic processes.
(Medaglia 2012, 345)	"e-Participation is the use of ICT to support democratic decision-making."	ICT to support democratic decision-making.
(Susha and Grönlund 2012, 373)	e-Participation "describes the domain as citizens' participation in the processes of public service provision at various stages in the production chain (planning, decision-making, implementation, evaluation), which is another evidence of the close ties between e-participation and e-government concepts."	Citizen participation related to all aspects of public services.

Citation	e-Participation Definitions	Definition Changes
(United Nations 2014a)	e-Participation is defined as "the process of engaging citizens through ICTs [Information and Communication Technologies] in policy and decision-making in order to make public administration participatory, inclusive, collaborative and deliberative for intrinsic and instrumental ends" (United Nations, 2014, pg. 61).	ICT use to facilitate collaborative policy and decision-making.
(Federici et al. 2015)	The term e-participation indicates the processes and structures through which ICT supports relationships amongst citizens, governments, and public organizations.	ICT use to facilitate stakeholder relationships.
(Zheng 2017, 424)	"e-Participation is defined as the use of ICT to support democratic decision-making."	
(Alarabiat et al. 2017, 2855)	"The concept of e-participation has introduced a new perspective on the usage of digital technologies in the public sector, which primarily seeks to reinforce citizens' interaction with policymakers (governments and politicians) and to enhance citizen participation in policy and government decision-making processes."	ICT use to reinforce interactions with policymakers.
(Zheng and Schachter 2017, 409)	e-Participation is "the use of ICTs to improve citizen participation and two-way interactions between government and citizens."	ICT use for 2-way interaction between citizen and government.

In 2004, the term ICT was added to the definition as an essential part (Macintosh 2004), and facilitation by the Internet was included in 2008 (Sæbø et al. 2008). The term ICT encompasses technologies that ease citizens' engagement and access to government-provided information through telecommunication tools. Technological advances in ICTs allow citizens to communicate in real-time with others using technologies such as instant messaging, blogs, and video chat. Social media websites like Facebook allow citizens to remain in contact with their government regularly. Modern ICT has created new engagement opportunities for citizens in which they can e-participate wherever they are located. For this reason, ICT use is interrelated with how modern societies are engaged with their government. Moreover, e-participation is a social activity, where ICT is the

mediator between citizens and their government. This definition highlights the key actors as *citizens* in e-participation activities and, therefore, as an important stakeholder to consider when looking at such initiatives' successes and impacts (Sæbø et al. 2008).

e-Participation is also defined as the use of ICT to support democratic decision-making (Medaglia 2012). In 2014, the United Nations summarized their years of work with e-participation and defined it as "the process of engaging citizens through ICTs in policy and decision-making in order to make public administration participatory, inclusive, collaborative and deliberative for intrinsic and instrumental ends" (United Nations 2014a, 61). In summary, e-participation describes how the relationships among stakeholders are mediated by ICT for the purpose of participatory government.

It is clear that whatever the specifically used definition, the e-participation phenomenon is related to the interplay between ICT, citizens, and government actors to facilitate involvement in government decision-making. Governments devise e-participation strategies using a wide range of ICT tools to enable opportunities for consultation and dialogue with citizens. Moreover, all the above definitions emphasize the importance of citizen engagement with ICT for enabling the collaboration between governmental and non-governmental actors (citizens). Second, in all these definitions, the government has a role to play; however, citizens are the key actors in the activities that directly influence decision-makers to create better communities. In summary, e-participation may be viewed as a governmental strategy to improve citizen collaboration with their government to benefit society. After reviewing the e-participation definitions in the literature, I define e-participation as any voluntary action by citizens using ICT for

the purpose of influencing collective affairs and public decision-making that affects their society.

The Role of e-Government in e-Participation

e-Participation is inherently linked to e-government initiatives for using ICT to deliver government information and services to citizens. In 2000, the Associate Director of the U.S. General Accounting Office, David McClure, shared his views on e-government with the U.S. Congress: "Electronic government refers to government's use of technology, particularly web-based Internet applications to enhance the access to and delivery of government information and service to citizens, business partners, employees, other agencies, and government entities. It has the potential to help build better relationships between the government and the public by making interaction with citizens smoother, easier, and more efficient. Indeed, government agencies report using electronic commerce to improve core business operations and deliver information and services faster, cheaper, and to wider groups of customers" (McClure 2000, 1). In essence, the focus of *e-government* is on the delivery of public information and public services electronically. e-Participation is entwined with e-government because both rely on the use of ICT. However, e-government is typically more about ICT use to deliver information and services to the public rather than on dialogue, consultation, or civic engagement activities. Table 2.2 shows the definitions of e-government from the IS basket of 8 research journals.

It is acknowledged that citizen engagement (i.e., e-participation) is a successful factor in e-government development (Haro-de-Rosario et al. 2018; Olphert and Damodaran 2007; Tolbert and Mossberger 2006; Wang and Luo 2018). For example, in

2019 the UAE was ranked one of the most visited countries in the world. The UAE e-government has more than 4,000 federal and local e-services on its portal and issued 2,382,111 electronic entry permits to the country in 2019 (UAE e-Government 2020). Millions of citizens were involved in the UAE's e-government program using ICTs and the Internet.

Table 2.2: e-Government Definitions in the IS Basket of 8 Journals[1].

Research Articles	e-Government Definition
(Carter and Bélanger 2005, 5)	"e-Government is the use of information technology to enable and improve the efficiency with which government services are provided to citizens, employees, businesses, and agencies."
(Tung and Rieck 2005)	e-Government, defined as "information system aided handling of public administration processes using information and communications technology."
(Henriksen and Damsgaard 2007)	"e-Government is government's use of technology, particularly web-based Internet applications to enhance the access to and delivery of government information and service to citizens, business partners, employees, other agencies, and government entities."
(Huang 2007, 151)	"e-Government refers to the transformation of traditional public sector services and processes into an electronic format with greater accessibility and interactivity to citizens."
(Kahraman et al. 2007, 284)	"e-Government is implementing cost effective models for citizens, industry, federal employees, and other stakeholders to deliver government information and services online by utilizing the Internet and the World-Wide-Web."
(Chan and Pan 2008, 125)	"e-Government can be simply defined as the use of information technology (IT) to facilitate the business of government."
(Phang et al. 2008, 99)	"e-Government broadly refers to the strategic application of IT to transform the public sector."
(Chan et al. 2010, 520)	"e-Government is the delivery of government information and services through the Internet or other digital means."

[1] The eight journals in the list are, in alphabetical order: European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic Information Systems, and MIS Quarterly

Research Articles	e-Government Definition
(Chan et al. 2011, 529)	"e-Government may be broadly defined as the use of ICT to facilitate government service delivery by enabling greater customer orientation, efficiency, effectiveness, citizen satisfaction, reduced bureaucracy, and national development."
(Feller et al. 2011, 358)	"e-Government is the widely accepted term used to describe …. the ultimate aim of achieving innovative forms of government and governance through the use of ICTs; and a holistic transformation of the management of human, technological, and organizational resources and processes."
(Bélanger and Carter 2012, 564)	e-Government is "the use of IT to enable and improve the efficiency with which government services are provided to citizens, employees, businesses and agencies."
(Venkatesh et al. 2016,87)	"e-Government is defined as the use of the Internet by government agencies to provide informational and transactional services to citizens."

In summary, e-government refers to a government utilizing ICT to improve public service delivery to citizens through transparent and accountable means. e-Government has more of a one-way communication emphasis. In contrast, e-participation focuses on the use of ICTs to improve citizens' direct and interactive involvement with government actors in a two-way mode of communication. While e-government and the delivery of public information and services to citizens is a worthwhile research stream, the present study's focus is on e-participation. I am studying e-participation rather than e-government because public administrations worldwide promote ambitious and costly e-participation tools and programs for citizens' participation, such as social media pages, government blogs, and mobile apps. These tools and programs to engage with citizens provide ample opportunities for researchers to investigate effective means and methods of e-participation.

ICT Leverages e-Participation Development

Leveraging citizens' use of and involvement with ICT has been a concern since the beginning of e-participation because applying ICT in the context of citizen engagement with politicians and governments creates a complex environment. Recent analyses of the e-participation environment distinguish at least three layers of complexity.

The first layer is fundamental and composed of an individual's computer literacy skills and ability to access the Internet. These components, computer literacy, and access, form the basic level of an individual's e-participation capability. The second layer of complexity adds to the basic level the elements associated with an individuals' reading literacy and cognitive skills to search for and analyze information. This level is more cognitive and results from the quality of an individual's education. The third layer includes the skills to achieve individual goals through the use of web 2.0 functionalities such as social media (Le Blanc 2020). Importantly, individuals are increasingly adopting and using ICT tools, such as the Internet and mobile devices, to access government information and services. As individuals' skills move into the third layer, the complexity increases between e-participations' actors: citizens, governments, and public or social-service organizations.

The main objective of ICT integration in participatory activities is to engage a broad range of citizens by using a variety of ICT tools that utilize different skill levels. This strategy will help ensure broader citizen involvement and dialogue, greater access to government information, and enhanced government transparency and accountability. As a two-way communication mode, ICT tools serve as a feedback mechanism from citizens to governments such that citizens are transformed into co-producers of value rather than

passive consumers (Berthon and Williams 2007; Medaglia 2012). Hence, a variety of ICT to accommodate a variety of computer literacy skills in the foundational layer of e-participation is critical.

In e-participation, ICTs are incorporated many different ways to facilitate different types of involvement. There are numerous examples, such as the innovative use of technology by government bodies to provide citizens access to policy information and then to retrieve citizen comments. In some countries, parliament found that citizen participation can influence their agenda; therefore, they established an e-petitioning system to fit into the parliament's regular business (Matthews 2020). In consultation procedures with citizens, ICT tools are utilized to ease government officials' efforts to deliver their opinions on specific issues, either privately or publicly (Wimmer 2007).

Many forms of ICT tools are available to support citizens' participation, and other tools are in development. This increases the complexity of citizen involvement in the second and third layers of e-participation because greater literacy and access are needed. Examples include but are not limited to tools like blogs, online polling, discussion boards, and video streaming (Medaglia 2012). ICT tools are connected to popular platforms such as Twitter, Snapchat, Facebook, Instagram, and YouTube. e-Participation tools are generally developed internally and include features that support interaction among citizens and government (Alarabiat et al. 2017; Bingham et al. 2005) to share non-biased information (Zheng 2017) freely. The evidence from the literature shows that achieving enhanced democracy goals and citizens' participation using ICT continues to be effective. However, limitations exist to e-participation currently. For example, research points out that e-participation would be enhanced with greater information availability

(contextual factors) (Lee-Geiller and Lee 2019; Päivärinta and Sæbø 2006), increased e-government activities (Wang and Luo 2018), and faster adoption of the technology environment (F. K. Chan et al. 2011).

In summary, ICTs have contributed to developing a range of e-participation activities between citizens and their governments. There is also evidence that greater effectiveness and involvement of citizens in e-participation occurs when citizens engage over a diverse range of ICT tools. e-participation can achieve significant benefits such as enhancing participation and active citizenship, ensuring innovative ideas for policymaking, engaging young people in policymaking, and finally, increasing political trust and legitimacy. However, the implementation of newer ICT tools suggests literacy (computer and reading) and access factors may negatively influence the growth of e-participation for some citizens and/or countries.

The Focus of Current e-Participation Research

Evaluating the e-participation literature is not an easy task because it requires a comprehensive understanding of the phenomenon's main components and its relationship with e-government. e-Government and e-participation factors overlap. For example, prior studies have identified factors that could affect the citizens' adoption of e-government services (Colesca and Dobrica 2008), such as demographic factors including educational level and prior Internet experience. Other studies examine the interdependencies among rural inhabitants' demographic attributes (Liu et al. 2014), suggesting that younger citizens who live in rural areas and have basic knowledge of current government policies are more willing to adopt e-government services. Additionally, social influences are found to influence their intention to use the services directly. e-Government studies

intersect with e-participation research and, as such, are helpful in understanding important relationships in e-participation.

Earlier e-participation studies focused on government projects such as e-democracy, then provided no structure to implement the findings (Macintosh 2004). Researchers have noted that as e-participation projects move towards completion, research appears to move away from activity description to evaluating the activities (Medaglia 2012). For example, a prior study identifies significant factors that drive citizens' satisfaction in using an e-participation portal (Malik et al. 2016), including citizens' experience, literacy, and education. Additionally, citizen satisfaction with participatory platforms may depend on government reform, regulatory structure, and managerial capacities (Medaglia 2012). In general, e-participation research has experienced a significant shift in focus away from activities and toward the study of e-participation effects. This shift of emphasis leads to a more balanced picture of contributions from actors, ICT, environment, activities, and contextual factors. The emergence of a balance among different aspects of e-participation may be interpreted as an indication of a higher degree of maturity of e-participation implementation globally (Medaglia 2012; Susha and Grönlund 2012).

In summary, recent e-participation studies focus on five components: *actors, environment, activities, contextual factors*, and *ICT* (Macintosh 2004; Medaglia 2012; Zheng 2017; Zolotov et al. 2018). See Table 2.3 below for examples of the elements of each component. Figure 2.1 shows the intersection of ICT with actors, environment, activities, and contextual factors. The matrix results in five different forms of research focus in the e-participation literature.

Table 2.3: e-Participation Research.

Research Focus Component	Elements
Actors	Citizens, Politicians, Government institutions, Voluntary organizations
Environment	The environment is often a web-based application that provides the physical enabling space for agents' ICT activities.
Activities	e-Voting, online political discourse, Online decision-making, e-Activism, e-Consultation, e-Campaigning, e-Petitioning.
Contextual Factors	Information availability, Infrastructure, Underlying technologies, Accessibility, Policy and legal issues, Governmental organization.
ICT	Internet, Telephones, and other telecommunications products.

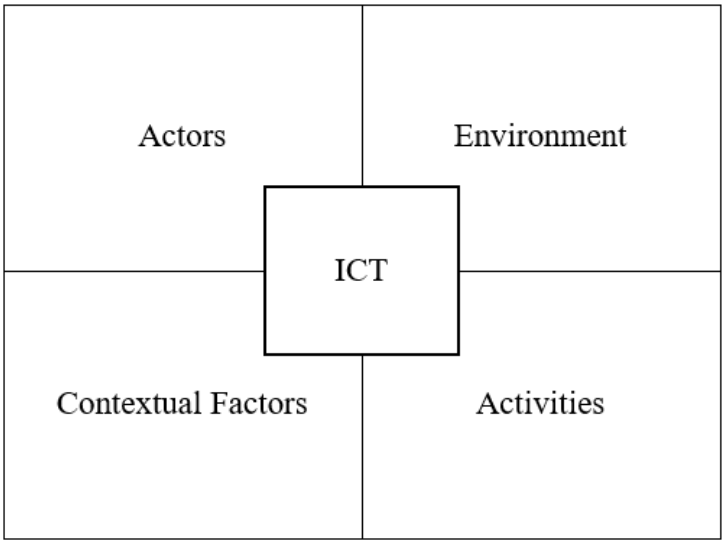

Figure 2.1: e-Participation Research Horizons

Actors

Actors are a significant factor in e-participation research because actors engage in various activities with their governments using ICTs. Much e-participation research focuses solely on the actors because they play crucial roles in e-participation processes. However, actors are often discussed in relation to the groups in which they reside and may consist of citizens, politicians, and government administrators. For example,

Øystein, Jeremy, and Judith (2010) suggest that politicians and citizens are the main actor groups in e-participation. These researchers believe that citizens may try to influence through traditional channels or through elected representatives; however, active citizens also seek to influence the political *process*. Furthermore, they argue that the focus of attention is rarely on politicians, and they are usually analyzed as a group of actors (Sæbø et al. 2010).

Anna Carola, Rony, and Jacob (2009) claim that "changing interactions between citizens, politicians, and administration introduced by e-participation" (Federici et al. 2015, 38) is beneficial to society. Moreover, they believe the relationship between actors (citizens, politicians, and government institutions) can be enhanced through e-participation, and society gains from a stronger connection between all actors. In some studies, the contribution to e-participation research is the focus on citizens as playing a crucial role in the process (Chen et al. 2006). For example, the potential of e-participation activities for engaging particular groups of citizens, such as youth, has been highlighted (Lee et al. 2003; Winkler et al. 2012).

Researchers also suggest that citizens' values are among the most vital factors influencing e-participation (Olphert and Damodaran 2007) and some studies describe government institutions or administrators as actors (Carlitz and Gunn 2002), that regulate e-participation. Voluntary organizations may also be actors involved in grassroots movements exploiting existing e-participation platforms (Howard 2005). e-Participation actors are also inclusive of platform users, citizens, politicians, government institutions, or voluntary organizations (Medaglia 2012; Sæbø et al. 2008).

Prior research identifies not only critical actors in e-participation, but also important characteristics of the actors. For example, e-participation actors' literacy and education characteristics are essential for developing targeted e-participation initiatives (Sæbø et al. 2008). The use of ICT in e-participation allows more actors to participate in the democratic debate in an online environment; thus, their contributions have the potential for more in-depth and broader influence. Although a variety of actors with various motives are involved in e-participation, their ICT literacy is a prerequisite for engagement.

Additionally, while citizens as actors are the principal focus for e-participation studies, politicians are also discussed with a focus on their interactions with citizens. Government institutions or voluntary organizations have also been the topic of research, often with a focus on a specific government service or services made available to citizens (Grönlund 2003; Sæbø et al. 2008).

Some e-participation studies focus on the relationships among actors. For example, e-participation was found to improve relationships between actors, and actors are encouraged to use social media to express their opinions (Kushin and Yamamoto 2010; Stieglitz and Dang-Xuan 2013). Social media helps governments understand their citizens and offers an alternative to government websites. e-Participation provides the opportunity to reach wider audiences in a more accessible (at any time and from any place) and understandable format in faster and more efficient ways (Lee and Kwak 2012).

In summary, the principal actors in e-participation in prior research are citizens and politicians. Actors' e-participation activities may result in improved engagement in the democratic process, a better quality of political deliberation, the inclusion of

marginalized groups of actors, and the transfer of policy-making elements to citizens, among many others. Moreover, actors may also act as information providers in e-participation where politicians' traditional roles as decision-makers and citizens as voters are not challenged.

Environments

e-Participation environments are spaces where actors engage in discourse that may be political in nature. The technological environment is where the back and forth of e-participation takes place. Research in this area highlights the environment as an important part of e-participation because it leverages the ICT tools used in actors' activities. Interestingly, the environment may be affected by changes occurring in the interchanges among actors, including stakeholder engagement, management, design, evaluation, and political process reshaping (Medaglia 2012; Rose and Sæbø 2010; Sæbø et al. 2010). The environment is structural, and thus hard to influence; however, it is an essential element to facilitate e-participation activities (Sæbø et al. 2010).

Recent studies suggest that it would be beneficial to investigate the technical aspects of e-participation (Medaglia 2012; Susha and Grönlund 2012). For example, there are still barriers to equal access to the World Wide Web. While disabled groups can easily engage in an online political discussion (Sanders 2007; Trevisan and Cogburn 2019), some studies focus on discrimination against disabled groups in the online environment, arguing that fully accessible services for all citizens remains elusive (Jaeger and Thompson 2004). Thus, researchers suggest governments should focus on accessibility in design to avoid the digital divide based on disability (Sæbø et al. 2008).

In summary, the environment in e-participation supports actors and their use of ICT tools in an interactive relationship. The environment is commonly viewed as a platform for actors' activities to provide feedback to bureaucracies, politicians, political institutions, or, more generally, policymakers or decision-makers.

Activities

e-Participation activities associated with technology are considered a social practice (Medaglia 2012; Zolotov et al. 2018). Social practice and ICT are recognized as inseparable in such cases, and e-participation actors perform those activities (Sæbø et al. 2010). In most cases, e-participation activities lead to outcomes or effects such as shaping actors' engagement in the democratic process, among others (Sæbø et al. 2008).

The range of activities engaged in during e-participation includes but is not limited to e-voting, online political discourse, online decision-making, e-activism, e-consultation, e-campaigning, and e-petitioning (Medaglia 2012; Zolotov et al. 2018). Many of these activities were traditionally offline and have opened new opportunities for actors in the electronic environment. Furthermore, citizens' social activities, such as donations, volunteer service, and environmental protection, have also been digitalized with opportunities for interactions with government entities. Many local governments have web-based services designed to help citizens report non-emergency issues, improve public sectors' response speed, and enhance trust between citizens and government (Lee and Kim 2012; Medaglia 2012).

In summary, actors' activities in e-participation are diverse. Actors' activities (e.g., e-campaigning, e-petitioning, e-voting) may result in improved engagement in the democratic process and a higher quality of political deliberation and discourse. e-

Participation activities may also increase the inclusion of traditionally marginalized actors' and transfer policy-making processes to citizens.

Contextual Factors

The research covering contextual factors focuses on issues that affect the e-participation process, such as information availability, policy and legal matters, and accessibility (Carter and Bélanger 2005; Medaglia 2012; Sæbø et al. 2008; Zheng 2017). For example, some studies focus on the functioning and accessibility of the ICT infrastructure as a necessary condition enabling the adoption of e-participation tools (Hwang and Mohammed 2008). Keeping in mind the ICT infrastructure is an essential element of e-participation in developing countries, weak ICT infrastructure is a barrier faced by governments seeking to implement e-participation. The literature is replete with studies demonstrating how in developing countries, poor ICT infrastructure remains a significant challenge during an e-participation implementation (Datta et al. 2005; Grönlund and Wakabi 2015; Ochara and Mawela 2015).

Other contextual factors in e-participation include the policy and legal issues that surround any e-participation initiative (Kosmopoulos 2004). In addition to the ICT infrastructure, legal issues are significant barriers to the implementation of e-participation. Other studies investigate complex challenges associated with governmental organizations concluding the organizational structures should be firmly in place before any e-participation initiative begins (Bingham et al. 2005). Similar to other online activities, physical, technical, governmental, and legal structures are required. In e-participation, these contextual factors will influence the operation of e-participation

activities as well as the outcomes or results of e-participation activities (Sæbø et al. 2008).

ICT

ICT tools mediate the interaction between governments and citizens in the framework of e-participation in democratic processes. Within the literature, e-participation research provides important insights regarding the utilization of ICT tools. However, the scope is broad and encompasses areas such as citizens' virtual participation, politics, and governance-related domains.

For example, the e-participation literature diverges into several different ICT streams regarding e-participation activities and emphasizes involvement with the technology environment at a high level (Medaglia 2012). Other studies emphasize website design as the number one factor (Lee and Kim 2014) or focus on the significance of ICT implementation (Phang and Kankanhalli 2008). Similarly, some research on ICT tools is directed toward a discussion of forum activities and procedures (Federici et al. 2015). At a basic level, ICT tools enable governments and policymakers to directly communicate with citizens and those for whom the policy is directed, in order to seek their input. Through this discourse, e-participation enables citizens to influence policy content through consultation earlier in the policy-making process rather than later, with greater influence and impact when discourse occurs early in the process (Macintosh 2004).

Scholars also discuss the challenges related to the characteristics and skills of e-participants, their interactions with ICT, and the outcomes. For example, a growing body of literature focuses on how governments are developing new ICT capabilities to enable

participation in policy formation and to encourage citizens to create greater information exchange with the government (Norris and Moon 2005; Zheng et al. 2014). However, citizens with low ICT literacy would be disadvantaged. Many governments have adopted various e-participation environments, such as electronic polls, political blogs, online forums, social media, electronic juries, and virtual discussion rooms. However, these advancements in e-participation are not universal. Developing countries have difficulty implementing any e-participation initiative due to their poor ICT infrastructure that dramatically limits information availability between citizens and their government. Yet, there is hope that mobile telephony can carry Internet services and provide vital coverage to underserved areas of the world (Bagui et al. 2016; Foli and Van Belle 2015). Importantly, the actors' experience with ICT is critical to the goal of implementing practical e-participation activities.

In summary, from an e-participation perspective, ICT tools enable citizens to engage in and learn about government structure, engage in decision-making, policy processes, and directly communicate with the government. ICT provides citizens the critical and necessary capabilities to facilitate involvement and dialogue with government actors and other citizens. However, citizens with low skill levels may not be able to participate fully.

Researchers also suggest that e-participation initiatives are a vital part of the national government's ICT policy strategies (Wright 2006). Because of ICT's increasing affordability for governments and citizens, the government's scope of engagement with citizens will increase and provide new possibilities and opportunities for actors' participation. Researchers argue that citizens' engagement and involvement would be

renewed and reinvigorated by ICT (Chun and Luna-Reyes 2012). Others claim that ICT will allow citizens to influence government policies from the bottom up (Abdelsalam et al. 2013). Furthermore, some researchers suggest that when governments provide different ICT channels for government communication, such as social media, then the number of actors who shape politics will increase (Bekkers et al. 2013).

e-Participation in the IS Literature

One aspect of the e-participation phenomenon is electronic services. Over the past two decades, research on electronic services delivered to citizens by their government has grown significantly in the IS literature. The meaning of the concept of electronic service "encompasses most of the concepts used to denote electronic interfaces between governments and citizens" (Lindgren and Jansson 2013, 165). Electronically mediated public services such as occur in e-participation are related to access to government information and governmental output, rather than the delivery of a service. Hence, e-participation also involves citizen rights and the protection of citizen rights.

The diffusion of electronic services in the IS literature is centered on electronic services adoption (Dawson et al. 2016; Magnusson et al. 2020; Olphert and Damodaran 2007), electronic service quality (Nishant et al. 2019; Tan et al. 2013), and electronic service consequences (Iannacci et al. 2019; Srivastava et al. 2016). Researchers have emphasized the urgency for research on factors that influence electronic service adoption (Tung and Rieck 2005).

There are numerous challenges associated with the promotion of electronic services to citizens, and governments should promote the proposed benefits to citizens with a clear plan to overcome challenges. Several challenges are discussed in the

literature, such as the level where government changes need to take place for electronic service to be successful in a given context (Irani et al. 2007; Sipior et al. 2011; Tan and Pan 2003). In developed nations, due to the phenomena of e-government with the provision of electronic services, there is demand for the use of ICT to facilitate citizens' engagement with their government. The widespread adoption of ICT by citizens is pushing decision-makers to adopt additional services because e-participation initiatives foster civic engagement and mobilization, better government services, transparency, and accountability (Bawack et al. 2018).

Importantly, there is ongoing research to identify the determining factors for participation adoption. For example, research demonstrates the strong association between U.S. counties' adoption of electronic services and positive socioeconomic factors such as education and income (Huang 2007). Other research discusses the benefits that governments could achieve from adopting a sociotechnical, participatory approach to adopting electronic services. They highlight the role of citizens' skills and capabilities to engage effectively throughout the adoption process (Porra and Hirschheim 2007). Additional studies highlight actors' skills and capabilities as key to developing government electronic services (Olphert and Damodaran 2007).

Another stream of literature is concerned with electronic service quality because citizen participation evolves through electronic activities in specific situations. Service quality perceptions have also been a topic of research to determine how to develop robust quality services. In a study investigating service quality perceptions, researchers conclude that service content and delivery not only comprise distinguishable elements of

electronic services but also are equally informative in explaining citizens' perceptions of electronic service quality (Tan et al. 2013).

In the area of electronic service success, a few studies explain how a significant portion of citizens' perceptions of e-government services success are based on certain factors, such as information quality and participation in decision-making (Scott et al. 2016; Venkatesh et al. 2016). These studies argue that government electronic service maturity is characterized by relatively stable trajectories punctuated by radical shifts toward full-blown government transformation. Other IS research focuses on privacy as a quality metric for electronic service delivery. For example, intellectual property protection and privacy may be a significant concern of citizens contemplating involvement in e-participation. The collecting and sharing of citizens' data is a serious matter impacting perceptions of privacy. These, as well as organizational and technical issues, may be barriers that need to be addressed and solved (Otjacques et al. 2007). Additionally, exploratory research provides preliminary insight into how corruption may be present in a nation's legal institutions when there is a lack of transparency and suggests that e-government can control the corruption mechanisms in nations (Srivastava et al. 2016).

Electronic services continue to grow rapidly. A significant number of citizens prefer it over traditional "off-line" face-to-face government services due to convenience and time-savings (Andersen and Henriksen 2006; Lips 2007). In fact, electronic services cover most citizens-to-government transactions and provide an interactive government information flow in the citizens' direction. Adding electronic services to a national

infrastructure can improve the quality of governance and socioeconomic development (Meso et al. 2009).

The positive consequences of electronic services may also contribute to e-participation maturity. For example, some scholars believe that the outcome of any study on government adoption of electronic services critically depends on the extent of government maturity during the time of the study (Cole and Jupp 2005; Tung and Rieck 2005). On the other hand, electronic services may also have a negative effect and facilitate malicious behavior between actors, such as competitiveness, bullying, and behavior to alter the system for one's benefit[2]. Alternatively, actors who use electronic services are more likely to have civic and technology skills. Importantly, the use of electronic services can increase actors' skills and efficiency over time, help advance new technologies, and attract more citizens. It is likely that individuals using electronic services would also be more involved in other e-participation activities.

While there seems to be substantial growth in government electronic service initiatives, it is unclear whether citizens will embrace those services and what factors will influence growth. The success and acceptance of the initiatives, such as e-voting and license renewal, are contingent upon citizens' willingness to adopt these services (Carter and Bélanger 2005). Numerous studies have analyzed citizens' adoption of government electronic service (Brown and Thompson 2011; Cordelia 2007; Gupta et al. 2008; Pan et al. 2006), finding that the alignment of technology and government processes can influence citizens' activities and their trust.

[2] https://www.stopbullying.gov/cyberbullying/what-is-it

The literature lacks comparative studies analyzing the mechanisms that underly and support the phenomena of e-participation and how it is established, as well as how it grows to reach more participants. Such studies would aid the involvement of citizens in developing countries with their governments. According to the United Nations Committee for Development Policy report in 2019, countries were classified into two groups: the least developed countries, such as Yemen, and developed countries, such as Australia (United Nations 2019); see (Appendix A Table A.2) for more details. In a developed country, citizens perceive that the benefits of their interaction with the government through e-participation initiatives are positively tied with the acceptance of the exchange (Alarabiat et al. 2017). Thus, the government may decide to start e-participation initiatives based on whether they believe citizens' input positively influences government policies and decisions (Medaglia 2012).

While e-participation research has progressed, there is a pressing need to identify core factors influencing the growth trajectory of e-participation among countries that have implemented e-participation initiatives. Currently, there is a lack of insight into the crucial factors that contribute to the growth of e-participation and how those factors change over time. Understanding these factors and how they contribute to e-participation will help developing nations flatten the learning curve and join the multitude of governments successfully engaging with their citizens. The present study addresses this gap. First, it generates a theoretical model of e-participation on the foundation of stigmergy theory. Then, country data is analyzed to identify the factors contributing to the positive growth trajectory of e-participation over time. The goal of this research is to

identify e-participation factors and understand how they contribute to e-participation over time.

CHAPTER THREE

Theoretical Foundation

Stigmergy Theory

Nature has inspired research in many ways. For example, birds' wings' structures were the first milestone in an airplane design (Keennon et al. 2012). For decades, biologists and zoologists studied the behavior of social insects to understand insect colonies and how they are capable of complex collective action such as reserve design (Partridge et al. 1996), habitat management (Westrich 1996), and habitat fragmentation (Boswell et al. 1998). Over the last 50 years, biologists have examined many of the mysteries surrounding social insects, and the last decade has seen much research utilizing the principles of stigmergy theory garnered from the field of entomology.

Stigmergy theory (Grassé 1959) is defined as "the notion that an agent's actions leave signs in the environment, signs that it and other agents sense and that determine their subsequent actions" (Parunak 2005, 2). In 1959, the French zoologist Pierre-Paul Grassé explained stigmergy as a class of mechanisms that facilitate animal-animal interactions. Stigmergy was initially described as a biological phenomenon by Grassé in his observations of social insects engaging in simple actions (Grassé 1959). Grassé observed insects' apparent coordination using cues within the insects' shared environment that resulted in a complex activity (e.g., food-collecting by ants or nest-building by termites). In the book "Stigmergic Optimization," chapter one introduces stigmergy (Crina and Ajith 2006); the authors interpret the French zoologist Grassé:

"Self-Organization in social insects often requires interactions among insects: such interactions can be direct or indirect. Direct interactions are the "obvious" interactions: antennation, trophallaxis (food or liquid exchange), mandibular contact, visual contact, chemical contact (the odor of nearby nestmates), etc. Indirect interactions are more subtle: two individuals interact indirectly when one of them modifies the environment and the other responds to the new environment at a later time. Such an interaction is an example of stigmergy" (Crina and Ajith 2006, 3).

Grassé studied nest construction in termites, finding that nest building does not rely on direct communication between individual insects. Instead, he discovered that the nest structure itself coordinates the workers' tasks, essentially through local pheromone concentrations. The study revealed that insect behaviors within the nest structure were triggered by the structure or traces in the structure (pheromones), which triggered work activity until the construction was complete (Crina and Ajith 2006). Grassé's research introduced stigmergy as a concept of successful coordination with no centralized management structure or direct observable intercommunication (Grassé 1959). In essence, stigmergy describes a process of indirect communication between one agent and another through the environment to create an outcome of greater complexity (e.g., nest). More specifically, one agent's behavior is influenced by other agents' behavior through their interaction with and within the environment, to the benefit of their society.

Stigmergy is observed in both natural and engineered human environments. In nature, stigmergy facilitates indirect collaboration among agents using signs or traces to trigger other colony members' responses. Essentially, an agent's traces (signs) are objects or molecules (scent) remaining in the environment, and these signs influence the

subsequent behavior of both the agent and other agents. In an engineered environment, some researchers studied Internet (network) collaboration and concluded that the stigmergy mechanism is at work in organized societies when a beneficial outcome is achieved without an apparent management structure (Dipple et al. 2014). The behaviors and activities of the agents are not managed or coordinated.

Within human social communities, two key factors define stigmergic behavior. First, each agent is self-organizing, so there is no central control or directed coordination of agents. Second, direct interaction or communication is minimal because agents are motivated to respond to environmental cues or artefacts (Dipple et al. 2014). For example, in a study about the self-organization of workers having no direct coordination other than the state of the work in construction projects (building houses), Lars Rune (2013) shows that cooperative work tasks are integrated through practices of stigmergic behaviors. One worker does not respond to the state of the construction (e.g., painter) until another worker (e.g., sheet-rocker) has completed the necessary wall preparation. Construction workers self-organize by observing the artefact (Christensen 2013).

A stigmergy system enables a lightweight and scalable mechanism based on self-organization principles. A stigmergy system is observed when the "repeated actions of the insects interact over time with the changing physical environment to produce a characteristic end state" (Holland and Melhuish 1999, 173). A stigmergy system aids organizations because it does not require a central management team (Dipple et al. 2014).

Self-organization, as the consequence of autonomy, is a key principle in stigmergy theory. Self-organization occurs when signs or artefacts are perceived in the environment by autonomous agents who interpret them and are motivated to action and

produce 'something' of greater complexity. Autonomous agents' individual work activities demonstrate self-organization which is evidenced by an outcome or emergence at a societal level (nest, trail) that benefits all agents. Moreover, the environment is the catalyst that transforms the artefact's static content by providing affordances (e.g., technology interfaces, tools) used by agents to develop or contribute to the artefact. The artefact itself represents a conceptual and significant accumulation of the agents' contributions (Dipple et al. 2012; Dipple et al. 2014).

Stigmergy in e-Participation

e-Participation represents a complex, societal outcome (or artefact) that is sought by countries in order to compete globally. e-Participation is centered on creating a public value and is co-created by citizens (Ju et al. 2019). Citizens develop what is referred to as 'e-participation' through indirect communication with their governments and other citizens in ICT mediated environments.

One theoretical framework for understanding e-participation is stigmergy theory. e-Participation results from stigmergic processes because autonomous citizens (agents) shape their country's governmental systems and processes by indirect communications within the e-participation system. Citizens' contributions are signs (or traces) that motivate other citizens to act or participate in the computer-mediated environment. ICT in the web-based environment mediates indirect communication among citizens, and e-participation grows as citizens are encouraged by the signs of other citizens to get involved. Table 3.1 describes the essential elements of stigmergy theory and how they are applied in this study.

Table 3.1. Stigmergy Theory Elements.

Stigmergy Elements	Definition
Agent	According to the dictionary, the word agent is "a person who acts on behalf of another person or group1." The agents in this study are individuals who engage in e-participation activities. e-Participation agents include citizens, politicians, government institutions, or voluntary organizations (Sæbø et al. 2008; Medaglia 2012). The agents interact with web environments using ICTs and contribute to the e-participation artefact.
Sign	Signs are a core component of stigmergy. Signs interface with both the environment and the agents. A sign is an intermediary between the agent and the environment (Huang et al. 2008). A sign is also a significant contribution event that has an instantaneous creation, diminishing through atrophy over time (Dipple et al. 2014). In e-participation, signs or traces are user-contributed elements that the web environment accommodates and sustains.
Environment	The environment contains the signs and represents them through its dynamics. It is the environment that provides the interfacing element for the agent who interprets both the sign(s) and the state of the artefact (Huang et al. 2008). The environment also performs the role of external memory for the agents. Generally, agents have no awareness of the current state of the overall environment. The environment is vital to facilitate the agents' action even without any direct communication. The e-participation environment is a web-based application that provides the physical enabling space for agents whose activities are mediated by ICT.

Australia offers a prime example of stigmergy and e-participation where citizen actors engage with the governments' web environment using ICTs to their benefit and the benefit of society. There are numerous government websites in Australia, and it can be challenging for citizens to find the information they seek. However, the Australian government created a specific website[2] to link citizens with information and services from about 900 other government websites. They did this by creating an icon at the

[1] www.dictionary.com

[2] https://www.australia.gov.au/

bottom of their website to link citizens to the official government Instagram page[3] as the official social media page (see Figure 3.1, Frame 1) from which to get information.

In October 2020 during the COVID-19 pandemic, the Australian government announced that New Zealand travelers could travel quarantine free to Australia (see Figure 3.1, frame 2 and 3). This announcement triggered the participation of 218 citizens who commented on the new directive, and it prompted 2705 'likes' (see Figure 3.1, frame 2). The announcement not only provided the needed information, but it encouraged citizens to start conversations about this directive (see Figure 3.1, frame 4 and 5). The online conversations are signs that promote the participation of other citizens, and they are also useful feedback for government. The 2705 'likes' are also signs encouraging the agents. Stigmergy is observed in the engagement of autonomous citizens and their interaction with the artefact (web announcement), each other, and the government using ICT. The citizens engaged in the discussion autonomously and without coordinative artifacts. The outcome is e-participation, a macro-level artefact benefiting the society of citizens.

[3] https://www.instagram.com/ausgov/

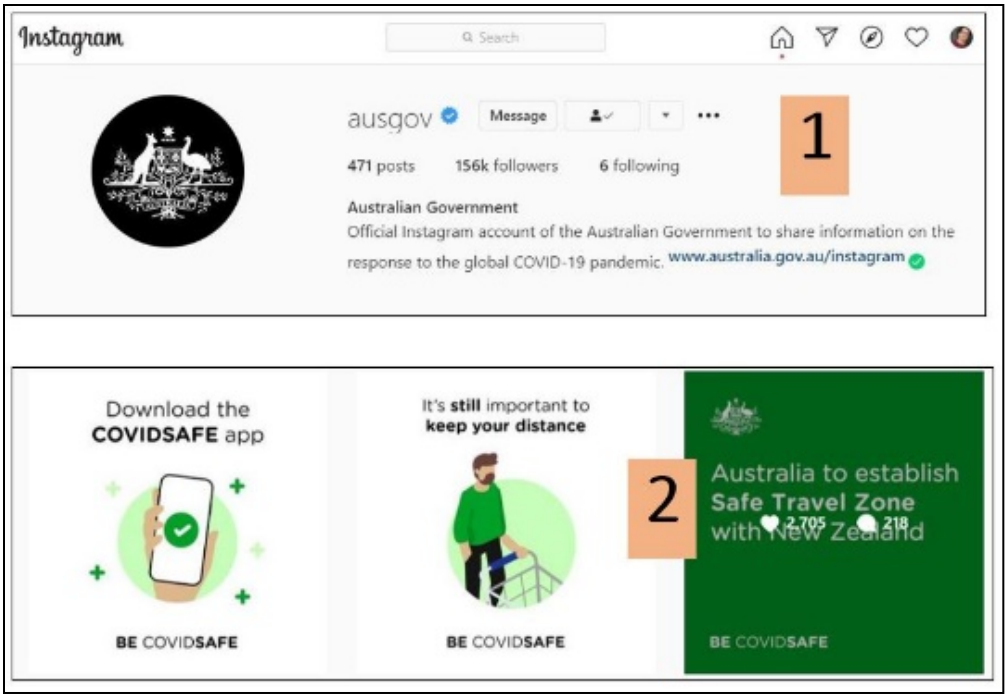

Figure 3.1, Frame 1 and 2 Australian Government Instagram

Figure 3.1, Frame 3

Figure 3.1, Frame 4

Figure 3.1, Frame 5

CHAPTER FOUR

The e-Participation Theoretical Model

The e-participation theoretical model of this study is shown in Figure 4.1. In IS research, a successful self-developed framework starts with generating model ideas based on theory (Hong et al. 2014). This study's model provides a broad perspective of the components of e-participation based on the framework of stigmergy theory. Autonomous agents interact with their environment and signs to achieve a beneficial social outcome – e-participation. I use this model as the basis for examining the growth of e-participation in terms of the significant factors propelling its growth. Overall, this study brings clarity to the evolution of e-participation among successful and less successful implementations in countries all over the world.

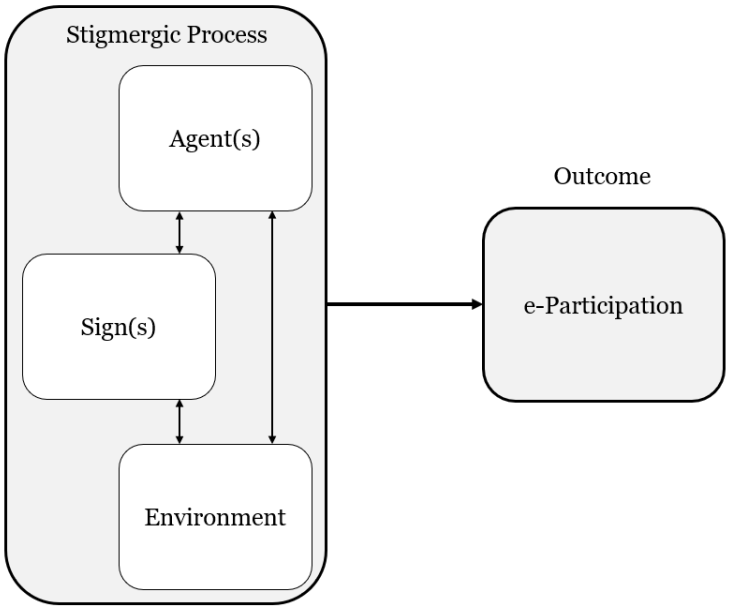

Figure 4.1: e-Participation Theoretical Model.

Figure 4.2 illustrates the biologic theoretical model that follows the stigmergy concept in nature. Figure 4.2 shows ants (agents) in their environment, doing what they do best, searching for food. The diagram illustrates the highly organized nature of ant societies and how they survive without an apparent management structure. In their environment, ants do not have direct communication; they are guided by other ants' traces or signs. The environment maintains the signs that trigger other ants' responses. This is the indirect communication mechanism of stigmergy (Dipple et al. 2014). Arrival at a food source is the outcome that benefits the society of ants.

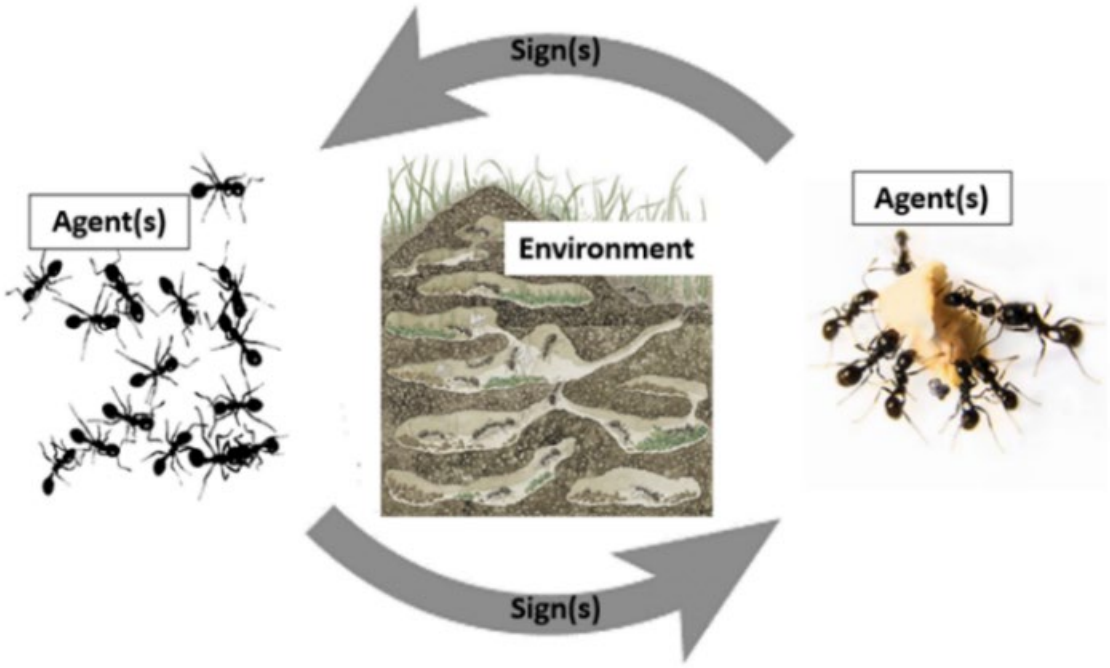

Figure 4.2: Stigmergy Theory

Figure 4.3 shows how, similar to nature, citizens' actions in a web-based environment are inspired or triggered by other citizens' actions, without direct communication. For example, citizens may leave discussions in a government blog

(sign) on a government website (environment) that influences the participation of other citizens who may respond in the web environment. The outcome is e-participation that benefits all citizens. Agents may include citizens, politicians, government institutions, or voluntary organizations. Signs may include blogs, comments, or 'likes' that remain in the environment and prompt other agents to participate and create the e-participation outcome.

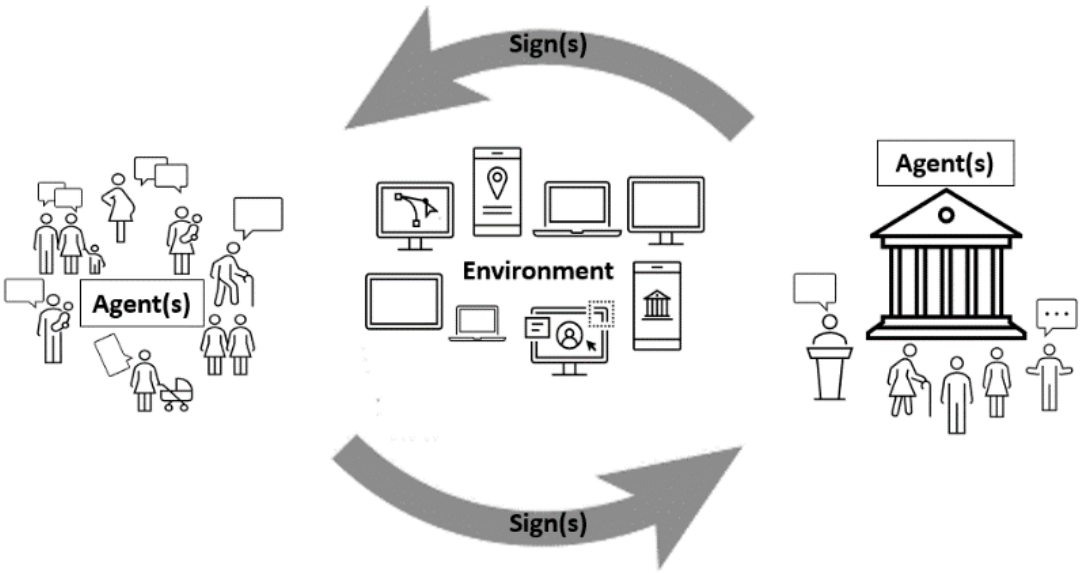

Figure 4.3: Stigmergy in e-Participation

Hypotheses

Before evaluating the growth trajectory of e-participation in countries worldwide, relevant and important variables related to e-participation must be discussed. In the following sections, I hypothesize variables and their relationships with e-participation. The variables were selected based on their conceptual association with the essential elements of stigmergy theory: agent, sign, and environment in the context of e-

participation. Figure 4.4 illustrates the e-participation factors in the framework of stigmergy.

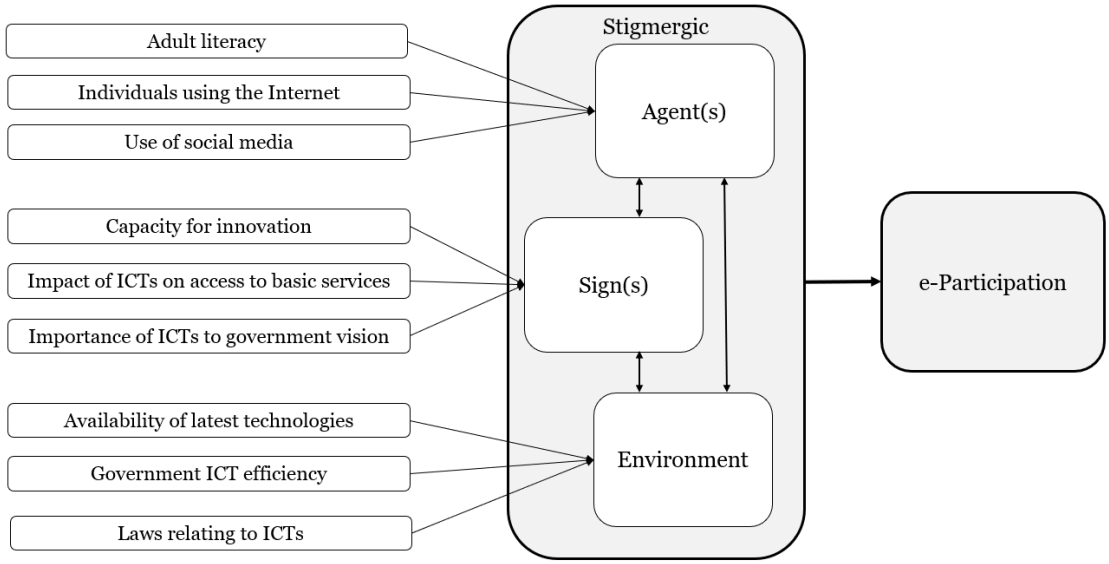

Figure 4.4 E-Participation Factors in Stigmergy Framework

Agent(s)

The agents in the model of e-participation are the first stigmergic element to consider. Stigmergy theory in nature requires that agents have the capability to respond to signs and artefacts in their environment. For a citizen to fully engage in e-participation (i.e., respond to the environment), the individual must possess fundamental skills such as literacy. "Adult illiteracy (or literacy) is defined as the percentage of the population aged 15 years and over who cannot both read and write with understanding a short, simple statement on his/her everyday life" (United Nations Educational, Scientific and Cultural Organization 2017). Logically, a citizen lacking the ability to read and write would not have the necessary skills to respond to signs (i.e., blogs, comments) in the web-based, e-participation environment.

Hypothesis 1a: Adult literacy is positively related to e-participation.

When the term "citizen" is used, it is often linked to the "end-user" concept that includes: their profile, their literacy, and their digital literacy (Simonofski et al. 2017). The literacy level (reading and computer skills) determines the range and depth of collecting and consuming information or data in web environments. It is striking that e-participation is, to some extent, an exclusive activity and that citizens may be excluded due to sociodemographic factors such as education quality, Internet skills, and age. For effective e-participation, the quality of the citizen's education would go beyond basic literacy skills to include computer and Internet usage skills. Higher-quality education would more fully prepare citizens to engage with their governments using ICTs. Citizens who have completed higher education levels are more likely to benefit from e-participation (Zheng 2017).

Some countries have started implementing computer classes in secondary schools to promote digital literacy. For example, as a strategy towards achieving the objective of fostering basic literacy and ICT literacy, the Malawi government will introduce computer lessons in education, especially primary and secondary education (Ziba 2007).

Researchers find that citizens with lower quality education use the Internet less frequently (Albrecht et al. 2008). A study concluded that age, Internet experience, and education quality are significantly related to citizens' engagement (e-participation) with their government (Sipior et al. 2011). Citizens' e-participation is particularly pronounced among those with higher incomes, high quality of education, and relevant skills (Verba et al. 1995). Thus, basic computer experience, such as what is delivered in the education system, would be necessary to function in the web-based e-participation environment.

Some countries provide opportunities for citizens' participation by facilitating citizens' education and skill development in order to bolster political discourse (Klein 1999).

Digital literacy skills in the 21st century also include social media. The use of social media enhances citizens' ability to access, interpret and understand government information. Currently, many e-participation technologies are Internet and social-media based and are often adaptations of well-known technologies, such as blogs and chat technologies (Alarabiat et al. 2017; Bertot et al. 2010; Sæbø et al. 2008). Numerous government initiatives depend on bringing citizens together by using social media, as illustrated in the prior example of Australia's government (Figure 3.1). Using social media, citizens can amplify their voices and communicate their expectations, desires, and frustrations.

The United Nations has incorporated public participation in social media as an important element of e-government. They evaluate how governments interact with citizens using Facebook, Twitter, YouTube, blogs, chats, SMS, etc. (United Nations 2014b). Other scholars believe Web 2.0 tools and social media have created a new environment that politicians and decision-makers have available to incorporate into day-to-day activities with citizens (Bonsón et al. 2012; Lee and Kim 2012). Social media is recognized as an important channel for agents' interactivity, and citizens with social media skills are better equipped to contribute to e-participation outcomes.

e-Participation is not a recent outcome, but rather an evolution of many existing activities facilitated by the Internet's widespread deployment (Sæbø et al. 2008). When citizens use the Internet and social media, they demonstrate the skills necessary for e-participation. The more experience citizens have, the greater their ability to navigate

government websites, receive government information, and interact with other citizens. Furthermore, social media is an indirect means to acquire more information, including other citizens' opinions, about new government policies posted on the Internet. It follows that citizens equipped with Internet and social media skills are better prepared to engage in e-participation, leading to the following hypotheses.

Hypothesis 1b: Use of the Internet is positively related to e-participation.

Hypothesis 1c: Use of social media is positively related to e-participation.

Sign(s)

The sign in stigmergy theory is the element in the environment that is left by one agent and triggers the response of another agent. A government website is an environment, and it contains the signs that motivate citizens' responses. Signs may be explicit, such as blogs, icons, applications, and comments, or implicit, such as rules for online discourse. In general, a sign represents a ‘deposit’ made in the environment by the government or a citizen that stimulates a response and may also provide a means or method to accommodate the citizen's response.

I propose that government innovations using technology are signs in a web environment that motivate citizens’ response, leading to e-participation. An innovation is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 2010, 1). Late in the '90s, it was fundamentally a new idea for the public sector to offer basic government services to citizens through ICTs (Avgerou and Bonina 2020). Governments had to develop new practices and procedures for this to materialize. Researchers state that offering basic government services through ICTs is a remarkable accomplishment for government and has emerged as one of the greatest

innovations in the public sector (Potnis 2010). As government services mediated by ICT effortlessly pervade a society, citizens will be more apt to engage in e-participation activities (Olphert and Damodaran 2007; Phang and Kankanhalli 2008) because they perceive this sign, are attracted to it, and respond. Hence, the innovation of providing access to basic government services in a web environment is an illustration of a sign to motivate citizen response and encourage e-participation.

There has been a gradual appreciation of the need to develop innovative applications to support citizens' participation in government. This awareness drives the development of technological innovations that enable a wider audience to contribute to government debate broadly and more deeply (Macintosh 2004). The rise of government investments in ICT infrastructure improves citizens' ability to engage in e-participation (Kahraman et al. 2007) and is a positive sign of government interest in e-participation. When citizens perceive the signs signaling the government's efforts to innovate and improve the ICT infrastructure, they are likely to be more willing to be active in participatory decision-making to increase government efficiency (Krishnan et al. 2013). When the government provides the necessary infrastructure and takes steps to enact its vision, they signal to citizens that their participation is valued. Citizens with a positive attitude toward the government's innovation efforts are more likely to respond and contribute to e-participation outcomes. Thus, I expect that the capacity for innovation in a country is a sign that encourages citizen e-participation.

Hypothesis 2a: Innovation capacity is positively related to e-participation.

In 2003, researchers suggested that ICTs are reshaping government and democracy, although the study is not specific about the characteristics of such changes

(Chadwick and May 2003). Some researchers suggest government services growth through ICT investment is an aggressive and risky strategy because, unlike organic growth and citizen partnerships, this growth strategy could quickly diversify new services and challenge the delivery of basic services (Medaglia 2012). However, recent studies have demonstrated a positive relationship between ICT impact and the delivery of basic government services (Susha and Grönlund 2012; Yates et al. 2010). As governments invest in ICT implementations and citizens realize benefits, trust will build between citizens and their government, and citizens are more likely to respond positively to ICT implementations. Thus, when basic services are provided using ICT, it is a sign of the government's vision to improve its citizenry and their communities. Basic service provision through ICT would encourage citizen response and e-participation, leading to the following hypothesis.

> Hypothesis 2b: Using ICTs to provide access to basic services is positively related to e-participation.

When governments invest in ICTs to benefit the citizenry, they emphasize the importance of ICTs in everyday government affairs. For example, countries may offer a new approach to the use of ICT in the creation of anti-corruption services. Many nations already have anti-corruption and transparency laws directly tied to the implementation of ICT initiatives (Bertot et al. 2010). However, as citizens perceive the significance of ICTs to hold government activities accountable, new ICT solutions that citizens believe will improve their lives would be viewed favorably (Von Haldenwang 2004). When governments have accountability, the country would be more competitive and improve economically. Such government actions are likely to be viewed as a sign that encourages citizen-government interaction and e-participation.

The value of ICT to governments is growing in practice and research. For example, in 2019 the ICT investment in the United States government was forecast to reach 167.9 billion U.S. dollars[1]. In terms of research, the government's implementation of ICT can offer new citizen-focused participation opportunities (Bertot et al. 2010; Medaglia 2012; Sæbø et al. 2008). It is likely that when citizens are convinced that government has a vision for using ICTs to help them and the country, citizens will interpret the government's viewpoint as a sign, leading to greater e-participation. This leads to the following hypothesis.

> Hypothesis 2c: Importance of ICTs to government vision is positively related to e-participation.

Environment

In stigmergy, agents interact with signs in their environments, and the interactions result a beneficial outcome. The main environment of e-participation consists of its technology infrastructure. The e-participation literature has previously focused primarily on ICT infrastructure as a form factor (Zolotov et al. 2018). In other words, prior literature identifies specific ICT infrastructures that are significant to e-participation outcomes. These include web-based platforms and ICT applications. Likewise, a growing body of literature describes government efforts to harness new technologies and create more robust information exchange with their citizens to enable more opportunities for e-participation (Kim and Lee 2017). For example, increasing government investment in ICT infrastructure advances its ability to attain maturity and increases citizens'

[1] U.S. Government ICT Investment 2014-2025, 2020.

willingness to engage in participatory decision-making, legal systems, and government efficiency (Krishnan et al. 2013).

The availability and use of current ICT technologies are critical for e-participation to occur and represent essential tools in the e-participation environment. Many forms of ICT have been developed or are in development to support citizen participation (Brown and Thompson 2011; Sæbø et al. 2008). Examples include but are not limited to Weblogs, electronic voting, chat, social media websites, mobile apps, and discussion forums systems. Various combinations of stakeholders' interest in participation and the ICT infrastructure development have resulted in many new projects designed to encourage and utilize citizens' engagement in political processes (Bekkers 2004; Kim and Lee 2017; Lee and Kim 2014). Thus, the greater the availability of current ICT infrastructures and tools to facilitate citizen interactions, the more likely citizens will e-participate with their government. This leads to the following hypothesis.

> Hypothesis 3a: The availability of the latest technologies is positively related to e-participation.

While an ICT infrastructure within a government's web-based environment is fundamental to e-participation, other more tacit structures are also imperative for citizen engagement. For example, governance factors that protect citizens and their rights in the web-based environment are necessary to encourage e-participation activities (Zheng and Schachter 2017). Another objective of e-government systems is to generate efficiency and rationalization at the government level to increase citizens' positive perceptions that government is customer-oriented (Chan et al. 2011; Chan and Pan 2008). According to the Global Information Technology Report: Government ICT efficiency means, “in your country, to what extent does the use of ICTs by the government improve the quality of

government services to citizens"[2] (pg.277). If the government's use of ICT does not effectively deliver the government's outcomes, citizens are not likely to participate and would resort to traditional means to acquire government services. Thus, the efficient use of ICT by the government is a tacit environmental element that will lead to greater e-participation, resulting in the following hypothesis.

Hypothesis 3b: Government ICT efficiency is positively related to e-participation.

Judicial independence is another example of a tacit environmental element surrounding a government-implemented web-based environment. Judicial independence can be defined as "a characteristic of individual judges, or as a characteristic of the judiciary as a whole, and most would agree that the ultimate goal can be described as the fair and impartial adjudication of disputes in accordance with law" (Law 2011, 37). Countries with strong laws are likely to see greater citizen participation activities in a government's web environments if the laws protect citizens' opinions. Without protection, citizen participation would be hindered if they believe negative consequences might occur from the public expression of personal opinion. Researchers propose that relevant ICT law in the web environment motivates citizen engagement (Bingham et al. 2005; Cooper and Gulick 1984).

Additionally, researchers propose intellectual property protection and ICTs laws should be elements of the overall government web environment to encourage citizens' engagement. The government should deploy more advanced security measures, such as digital rights management and public key infrastructure, to increase citizens' trust in their government (Chan et al. 2011). Increasing citizen trust concerning interactions with the

[2] https://www.weforum.org/reports/the-global-information-technology-report-2016

government may prompt governments to use ICTs to improve their efficiency and to offer high-quality information, and provide more effective ICT tools (Chan et al. 2011). When citizens believe the government-implemented web environment offers them useful and effective protection, they would be more likely to e-participate.

Researchers found that by the end of 2004, 59 nations had pursued transparency and freedom of information laws compared to the 1980s when only 11 countries had done so (Bertot et al. 2010). Not only will relevant laws increase citizens' protection beliefs, but researchers believe establishing ICT laws would provide countries and their governments with greater transparency to fight corruption (Relly and Sabharwal 2009). In concert with budgetary spending, laws, and regulations also shape society (Held 2006; Sæbø et al. 2010). Thus, establishing effective ICT laws can influence citizens' attitudes toward their government and its e-participation strategies. Although the nature of laws and the enactment of laws varies significantly from country to country, improving the scope and enforcement of ICT laws is likely to encourage citizens' e-participation. Based on this reasoning, I hypothesize the following.

Hypothesis 3c: Laws relating to ICTs are positively related to e-participation.

e-Participation activities in technology mediated environments lead to positive outcomes and benefits to society, including greater citizen engagement in the democratic process (Sæbø et al. 2010). When a citizen is engaged and active in an e-participation environment, signs remain in the web environment (e.g., commenting on a government blog). These signs serve to stimulate the subsequent activities by the same citizen or other citizens. ICT tools mediate citizens' engagement in the web environment. They ensure interactions occur independently without any need for planning, control, or direct

interaction with other agents. The result is greater e-participation for the benefit of society. This is the dynamic of stigmergy. Citizen agents serve as a momentum force for e-participation development that benefits all citizens and provides better outcomes for society (Zheng 2017). Citizens are e-participation agents, critical to e-participation development (Medaglia 2012) because their perceptions, values, and behaviors are important factors influencing the e-participation environment for better outcomes (Bošnjak et al. 2008).

CHAPTER FIVE

Methodology

This study utilizes quantitative methodologies to test the hypothesized relationships between the stigmergy-based factors and e-participation worldwide. The methods help clarify how the factors contribute to the growth trajectory of e-participation over time. To begin, I detail the origination and chronology of each of the four archival datasets used to gather the data for analyses. Then, I discuss the Latent Growth Curve Modeling (LGM) method that is used to examine how each variable contributes to e-participation over time.

Data

The data used in the present study were obtained from several different publicly available archival datasets that are discussed in detail below. The datasets present data collected from countries worldwide about many aspects, including the country's education, economy, labor market, and infrastructure. The datasets also include information about a large number of countries that have implemented e-participation at the national level.

e-Participation Index Dataset

The first set of data important to my research is the e-Participation Index (EPI). The EPI's primary source is the United Nations Global E-Readiness Reports and the United Nations E-Government Survey. The United Nations began collecting country-

level data about e-readiness in 2001 and data for the United Nations E-Government Survey in 1999. Both are a combined effort by the Division for Public Administration and Development Management (DPADM) of the United Nations and the Department of Economic and Social Affairs (DESA). The main idea behind collecting data at the country level is to assess the extent of e-government and a country's readiness for e-participation. The data is collected from all the United Nations Member States every two years, and a composite index of e-readiness is produced based on country characteristics such as website assessment, telecommunication infrastructure, and human resource endowment, among others.

In general, the survey data serves as an information base for those in the decision-making seats to help them identify their country's strengths and challenges related to the development of e-participation and e-government. It is important to understand that the United Nation's findings, based on their survey data, demonstrate considerable differences in the access and use of ICT across countries. The United Nations determined these are global issues and that concerted action needs to occur at the national, regional, and international levels to address the disparities. In general, the United Nations believes that providing information to track national and global e-government development trends and the lessons learned from worldwide practices, would help all nations improve their e-participation strategies in less time. The United Nations' overall purpose is to foster the development, promotion, and use of ICTs for social inclusion and economic development, along with the advancement of environmental protection (AbuJarour and Krasnova 2017; Kozma 2005).

The e-participation Index (EPI) is a one-of-a-kind measure that captures vital information that is not otherwise available globally. The dataset from which the EPI is derived contains ten pillars under which are 51 factors with an average of three questions for each factor. Examples of some of the pillars include but are not limited to: Political and Regulatory Environment, Infrastructure, and Economic Impacts. Additionally, the dataset consists of four different subindexes such as: e-Government Index, e-Participation Index, Online Service Index, Human Capital Index, and Telecommunication Infrastructure Index. All items in the survey are measured using 1-7 likert-type scales.

The EPI survey was developed with high quality standards by the United Nations. As an example of the information gathered in the survey, there are questions to determine the efficiency and utility of a country's knowledge and services to involve citizens in public policymaking. The survey's main aim is to rank countries based on their use of e-information[1], e-consultation[2], and e-decision-making[3]. As a result, the index reflects each country's ability and willingness to encourage citizens to engage in deliberative, participatory decision-making regarding public policy, as well as in its own socially inclusive governance program.

The EPI survey data is collected every two years, and the data collection process has been constant especially after the United Nation's innovation plan to set worldwide sustainability development goals. This dataset is the source of the e-participation construct (EPI) used in my study. I collected country-level EPI data across the years

[1] Enabling participation by providing citizens with public information and access to information without or upon demand.

[2] Engaging citizens in contributions to and deliberation on public policies and services.

[3] Empowering citizens through co-design of policy options and co-production of service components and delivery modalities.

2014, 2016, 2018, and 2020 for several reasons. First, and primarily, the e-participation data is only collected every two years, and the time span must be congruent with the data collected from other datasets. Additionally, while the EPI dataset is a well-established dataset in which the United Nations have collected survey data since 2003, not all countries were represented in 2003. For example, the United Nations evaluated e-participation worldwide in describing the 193 nation-states and confirmed that only 183 states have recently been posting online information "e-information" about education, health, finance, environment, social protection, and labor. Furthermore, in 2016, 41 member states did not employ social network features such as e-consultation to implement new policies or regulations, and only 120 members had developed e-decision-making tools (United Nations 2016). Thus, to include as many countries as possible in my analyses, I limit the data to the years 2014-2020.

Executive Opinion Survey Dataset

The second dataset is from the World Economic Forum, which uses the Executive Opinion Survey (EOS) data to show top business executives' contributions to their countries' economies. The EOS survey is a tool for assessing national competitiveness. This survey gathers top business executives' opinions on a broad range of significant competitiveness aspects for which complex data are scarce or nonexistent (Schwab and Sala-i-Martin 2019).

The EOS survey offers a unique source of insight and a qualitative portrait of each country's economic and business climate, as well as a comparison to other countries' situations. The first competitiveness study was published in 1979 and based on survey data from only 16 European countries. The survey captures data over 13 sections,

including the following: Overall Perceptions of Your Economy, Government and Public Institutions, Infrastructure, Innovation and Technology, Company Operations and Strategy, Education and Human Capital, Corruption, Ethics, Social Responsibility, Environment, and Health. The majority of the survey's questions ask respondents to rate one aspect of their working environment on a scale of 1 to 7. At one end of the scale, 1 represents the worst possible scenario, while 7 represents the best possible situation. The EOS results have been routinely used by various foreign and national associations, government agencies, academia, and private-sector companies for policy and strategy reviews.

International Telecommunications Union Dataset

I also use an archival dataset from the International Telecommunication Union (ITU) in my study. It identifies, defines, and produces official international statistics covering the telecommunication/ICT sector. The ITU verifies and harmonizes the data it receives from individual countries and collects missing values from government websites and operators' annual reports, particularly for countries that do not reply to the questionnaires.

The data contains demographic, macroeconomic, and broadcasting statistics. Also, more than 180 telecommunication/ICT statistics, including fixed-telephone networks, mobile-cellular telephone subscriptions, mobile-broadband subscriptions, fixed-broadband subscriptions (total and by speed tiers), international bandwidth, ICT costs, and statistics on ICT access and use by households and individuals, are available in the ITU database. A list of the ICT database sections is provided in Appendix A Table A.3.

United Nations Education, Science and Culture Organization Dataset

Finally, the Institute for Statistics of the United Nations Education, Science, and Culture Organization (UNESCO) is the official and trusted source of globally comparable data on education, science, culture, and communication. Every year, the official statistical agency of the United Nations publishes a broad range of cutting-edge databases to support the strategies and investments needed to change lives and move the world toward its development goals. From 1970 to the most recent year available, 2020, the UIS offers free access to data for all UNESCO countries and regional groupings. Developers and researchers are encouraged to create websites and applications to make extensive use of UIS disseminated data. The UIS includes a data explorer and a bulk data download service in addition to a robust standards-based website. I adopt only one variable from this dataset, the "adult literacy rate" indicator. The UIS gathers data on adult literacy from both sexes, and the data is self-reported by the governments of participating countries.

Dissertation Dataset

The data used in my study were collected from the four distinct archival datasets discussed above and originating with the United Nations. The United Nations is a legally regulated, reputable, global data collection organization with internationally accepted data collection processes. Table 5.1 provides a summary of each e-participation factor, its definition, and source. Each factor is captured for each of the 147 countries from the years 2014, 2016, 2018, and 2020. The replicability and generalizability of the data used in my study offers two significant advantages. Replicability is developed by using publicly accessible and commonly used data. The fact that almost every nation is represented ensures generalizability. It is worth mentioning that all factors are collected

yearly. However, the EPI is collected every 2nd year; therefore, to be consistent, I used data from the various datasets to match the EPI data collection of every two years (2014, 2016, 2018, and 2020) as a time period for this study's measurements.

Table 5.1: Indicators of e-Participation

Factors	Definition	Data Source
Adult Literacy Rate	Adult literacy is defined as the percentage of the population aged 15 years and over who can both read and write with understanding a short, simple statement on his/her everyday life.	United Nations Education, Science and Culture Organization.
Individuals using the Internet	Percentage of individuals using the Internet. Internet users refer to the proportion of individuals who used the Internet in the last 12 months.	International Telecommunication Union (ITU).
Use of virtual social networks	In your country, how widely are virtual social media networks used (e.g., Facebook, Twitter, LinkedIn)?	World Economic Forum, Executive Opinion Survey
Capacity for innovation	In your country, to what extent do companies have the capacity to innovate?	World Economic Forum, Executive Opinion Survey
Impact of ICTs on access to basic services	In your country, to what extent do ICTs enable access for all individuals to basic services (e.g., health, education, financial services, etc.)?	World Economic Forum, Executive Opinion Survey
Importance of ICTs to government vision	To what extent does the government have a clear implementation plan for utilizing ICTs to improve your country's overall competitiveness?	World Economic Forum, Executive Opinion Survey
Latest technologies	In your country, to what extent are the latest technologies available?	World Economic Forum, Executive Opinion Survey
Government ICT efficiency	In your country, to what extent does the government's use of ICTs improve the quality of government services to the population?	World Economic Forum, Executive Opinion Survey
Laws relating to ICTs	How developed are your country's laws relating to the use of ICTs (e.g., e-commerce, digital signatures, consumer protection)?	World Economic Forum, Executive Opinion Survey.

Latent Growth Modeling (LGM) Method

The objective of my study is to understand citizens' perceptions of factors related to e-participation and how those perceptions change over time. Thus, I use LGM because it is a longitudinal data analytic approach that measures changes in latent variables over

time. With the data I collected, the LGM procedure can evaluate a vast number of models, but I have limited the scope of my study. I use the LGM method to test the hypothesized determinants of e-participation to capture their effect on e-participation over time. I also use the method to model the factors grouped into the agent, sign, and environment roles of stigmergy theory. Additionally, I evaluate changes in the e-participation factors according to the country's 'developed' or 'developing' status.

Latent Growth Curve Modeling

Historically, growth curve models (e.g., (Potthoff and Roy 1964)) have been used to model longitudinal data in which repeated measurements for some outcome variables are observed multiple times. Exploratory factor analysis (EFA) and principal components analysis (PCA) literature are the latent growth curve method's foundations. Factors or components are conceptualized as aspects of change or chronometric (as opposed to psychometric) factors, and loadings are interpreted as parameters reflecting the repeated measures' reliance on these unobservable aspects of change (McArdle 1989; McArdle and Epstein 1987). Although linear, quadratic, or S-shaped patterns are also examples of these aspects of transition, there are a variety of concerns with these methods when it comes to researching transition. For example, rotational indeterminacy is a major barrier to putting these methods into operation, and there are no straightforward criteria for selecting a loading pattern that conforms to interpretable aspects of transition (e.g., a set of polynomial curves) (McArdle 1989; McArdle and Epstein 1987).

In 1990 latent curve analysis (LCA) defined as a form of confirmatory factor analysis (CFA) that allows researchers to define loadings that represent specific hypothesized trends in repeated-measures data, thus avoiding the rotational

indeterminacy issue (Meredith and Tisak 1990). The LCA method is similar to what is referred to as LGM. Because LGM implements CFA, a special case of structural equation modeling (SEM) developmental curve models can be embedded in larger theoretical models. In (2006), others provide a detailed review of LGM's historical development for readers interested in more information (Bollen and Curran 2006).

LGM describes a broad class of statistical methods that permit better hypothesis connection, provide enhanced statistical power, and allow greater correspondence between the statistical model and the theory under investigation relative to competing methods, such as cross-sectional models (McArdle and Epstein 1987). Researchers began using LGM because they were interested in understanding change over time. LGM estimates inter-individual variability and intra-individual patterns of change and also provides group-level statistics such as mean growth rate and mean intercept. Additionally, LGM can test specific trajectories in research hypotheses by incorporating both time-variant and time-invariant covariates (Preacher et al. 2008). LGM is a versatile SEM technique and is an alternative approach to capturing within individual shift trends. It expands the analytic power of growth modeling by mapping the multilevel model for change onto SEM.

Change takes time, and as a result, the timing of evaluations in growth models is critical for understanding change. The time variable contributes to the investigation of various change processes (Ram et al. 2010), and data is ordered and interpreted in growth modeling based on a researcher-selected time variable (Grimm et al. 2017). The chosen time variable should, in theory, act as an effective proxy for the change mechanisms and accurately represent how those mechanisms advance. Thus, the time variable is a proxy

for a particular form of operation. Because the e-participation factors are measured and collected bi-annually by the United Nations, they are good indicators of change over defined time periods across countries. Hence, LGM is appropriate for testing the change of the e-participation factors within and between countries over time.

Advantages of LGM

The LGM approach offers advantages over competing methods because it was designed to address questions concerning change over time (Chan and Schmitt 2000). LGM uses a flexible SEM technique that comprehensively assesses the changes within and between, as well as examining the differences in these changes (Singer et al. 2003). By mapping the multilevel model for SEM changes, LGM is an alternative approach to confirm within and between e-participation change patterns. Many researchers have argued in favor of LGM superiority over other analytic approaches because the LGM approach offers advantages such as flexibility in testing different research hypotheses about developmental trends that other approaches fail to provide (Curran 2000; Duncan et al. 2013; Little et al. 2000).

LGM is the preferred method for this study because it is a straightforward technique to compare growth or development across multiple groups or populations over defined periods of time. Figure 2 shows the unconditional LGM model. The unconditional growth model consists of a series of repeated measures of the same variable (with a minimum of three repeated measurements) where "i" represents an individual, and "t" represents the time-ordered measurements of Y (Fan 2003). This can be better understood using the following formula for the univariate model:

$$Y_{it} = \alpha_i + \beta_i \lambda_t + \varepsilon_i$$

α_i : represents the intercept of a variable's growth trajectory.
β_i : represents the slope of a variable's growth trajectory.
λ_t : represents the consecutive measurement time points.
ε_i : represents the modeling residual.

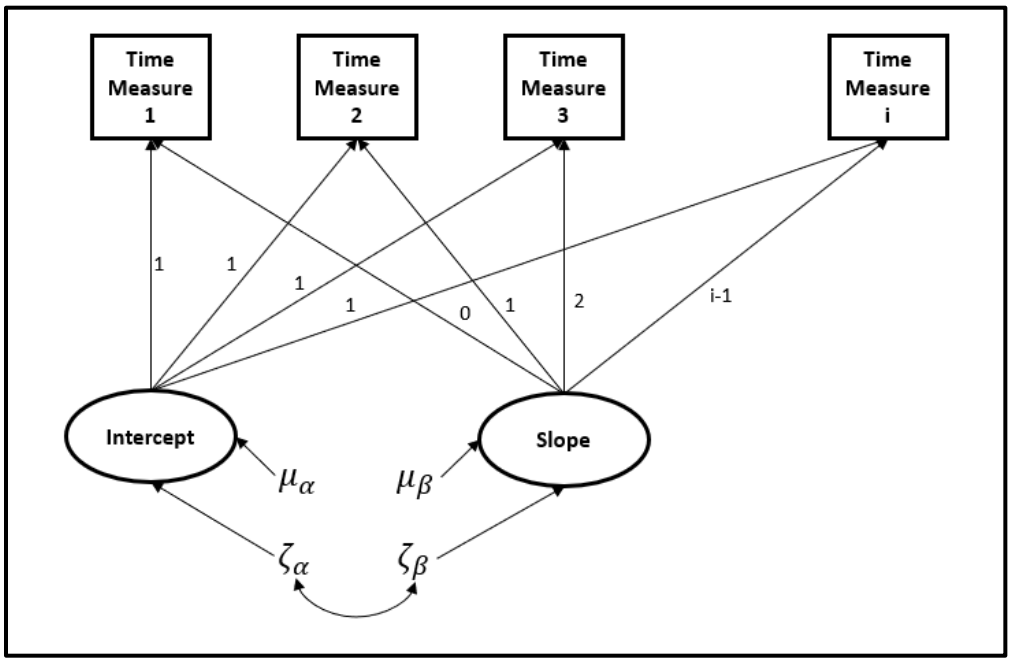

Figure 5.1: Unconditional Latent Growth Model (Adapted from Fan 2003).

In research, a common method to analyze developmental trajectories is using standard growth analyses such as repeated measures Multivariate Analysis of Variance (MANOVA) or SEM (Jung and Wickrama 2008). For example, in a given sample, these standard growth analyses estimate a single trajectory that averages all participants' individual trajectories. The average trajectory contains an averaged intercept and an averaged slope for the entire sample using an independent variable (such as time) to delineate the strength and direction of an average pattern of change through time for an entire sample (Andruff et al. 2009).

Using LGM instead of rival approaches like ANCOVA and multilevel modeling has several advantages. LGM enables researchers to explore inter-individual variations in change over time as well as the antecedents and implications of change. LGM offers group-level statistics such as mean growth rate and means intercept, as well as the ability to test theories about *individual* trajectories and incorporate both time-varying and time-invariant covariates. LGM has many of the benefits of SEM, such as determining model adequacy using model fit indices and model selection parameters, the ability to account for measurement error using latent repetitive steps, and the ability to deal effectively with missing data (Bentein et al. 2005; Chan 2002; Preacher et al. 2008). With LGM, it is less difficult than other methods to compare development across different groups or populations. LGM is a highly adaptable modeling approach that can quickly adapt to new circumstances with unique requirements.

LGM is considered a special case of SEM. In LGM, the measured variables are repeated measures of the same variable y. In a basic LGM, two factors or more are often specified to represent aspects of change. These factors are defined by specifying factor loadings of repeated measures of y in such a way that the factor loadings describe trends over time in y. The level of the outcome measure y is represented by the intercept factor, when the time variable equals zero, and the slope factor represents the linear rate at which the outcome measures change (Preacher et al. 2008). This general model represents the vector of observations (y).

The objective of my research is to understand the contribution of individual factors to e-participation over time; how e-participation develops. Thus, an analysis of each factor's trajectories over time is key to determine how e-participation develops. In

general, multiple antecedents can be applied over time, and statistical analyses of repeated measures will be used (Mobley 1982) to examine the e-participation factors dynamically. LGM enables me to investigate e-participation developmental trajectories while determining each e-participation factor's variability over time. (c.f., (Meredith and Tisak 1990)). In summary, LGM is a dynamic methodological approach with two essential aspects: time and change.

Additionally, I will segment the dataset to understand e-participation growth trajectory from different perspectives. The United Nations classifies the nations worldwide based on human development, political stability, gross domestic product (GDP), industrialization, freedom, and more. As a result of this classification, countries worldwide may be classified into two categories: developed and developing. According to the United Nations, in comparison to other countries, a developed country is a sovereign state with a developed economy and technologically advanced infrastructure (United Nations 2016). On the other end, developing countries are those that have not yet reached their full potential (United Nations, 2016). However, when considering factors such as standard of living, gross domestic product, and per capita income, developing countries have the potential for *greater growth.* Thus, the words' developing' or 'developed' refer to a country's current state rather than its evolving dynamics or future development.

In the annual human development report, the United Nations compiles data on countries' human development. They take into account a country's health, education, and income to provide a measure of human progress that is comparable across countries and over time. The data used in this process comes mainly from United Nations agencies and

international institutions. This process classified countries around the world into two categories of developing and developed countries. There are no universally agreed criteria that describe why countries are classified by their degree of growth. However, this may be attributed to the wide range of development results across countries, as well as the difficult task of categorizing each nation into two groups. The history of developing/developed countries' taxonomy became common in the 1960s as a way to categorize countries more effectively in the sense of policy discussions about moving wealth from more to less prosperous countries (Pearson 1969). Appendix A Table A.2 lists the United Nation's categorization of developed and developing countries that I use to segment my dataset into two groups.

RStudio Software

RStudio software will be used to perform the LGM analysis of the e-participation data. RStudio is an integrated development environment for R, a programming language for statistical computing and graphics[4]. A few different packages for the LGM analysis, such as lavaan, lme4 and nlme will be implemented to complete the LGM analysis.

[4] www.RStudio.com.

CHAPTER SIX

Analysis and Findings

In this part of this research, I present the findings that the analysis of the data revealed. As discussed previously, to evaluate changes over time in citizens' engagement with their government using ICT (e-participation), I implemented LGM analysis. I utilized the statistical software "RStudio" to test the hypotheses. In the analyses, I used manifest variables for each time point, multiple indicators for each stigmergy element, and then grouped the countries into developed and developing for more insights. The aim was to examine latent growth in the e-participation factors in several ways. More specifically, this study follows the guidelines and examples of others prior research (e.g.,(Bentein et al. 2005; Lance et al. 2002; Lance et al. 2000)).

My primary evaluation of the research hypotheses used both a univariate method and a multiple-indicator LGM analysis in Part 1 and Part 2 below. The simplest model is the univariate LGM that determines the intercept (status) and slope (rate of change) for T0-T3. These show the within-country (intra-country) change pattern over time for each e-participation factor. The objective of the second part is to determine the nature and magnitude of the change in the e-participation factors as a function of the e-participation index (EPI).

In summary, the univariate LGM captures intra-country change and shows the latent trajectory of change for each of the e-participation factors across the four time periods. LGM estimates the means and variances of the latent indicators the intercept and

the slope. The year 2014 serves as each country's initial status (T0) for each factor. Then, in the multivariate analysis the latent change in each factor is captured concurrently with the change in the e-participation index. This produces a multivariate analysis of change to examine the interrelationships among the latent trajectories in multiple e-participation factors. The isolation of vectors of change in the factors allows evaluation of the expected influence of factor changes on actual e-participation, or the EPI. Thus, the method enables hypothesis testing and understanding of the nature of e-participation change.

Descriptive Statistics

The dataset consists of nine factors contributing to e-participation across 147 countries over four years, yielding over 6,560 data points. The descriptive statistics and the correlations for the e-participation variables across time are presented in Table 6.1. The correlation matrix shows the relationships between the constructs from years 2014 (T0), 2016 (T1), 2018 (T3), and 2020 (T4). Table 6.1 also presents the standardized mean and standard deviation of each construct for the 147 countries.

Table 6.1. The Correlation Matrix

No.	Factor	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Lit0	2.17	0.82	1																			
2	Lit1	2.11	0.86	0.28	1																		
3	Lit2	2.04	0.78	0.31	0.32	1																	
4	Lit3	2.92	0.82	0.28	0.25	0.29	1																
5	Int0	3.4	0.94	0.27	0.27	0.21	0.24	1															
6	Int1	3.64	0.96	0.34	0.33	0.31	0.25	0.24	1														
7	Int2	4.14	0.87	0.26	0.28	0.13	0.31	0.27	0.24	1													
8	Int3	4.83	0.81	0.31	0.26	0.23	0.34	0.25	0.26	0.24	1												
9	Soci0	3.87	1.5	0.28	0.29	0.29	0.23	0.23	0.31	0.25	0.34	1											
10	Soci1	3.81	1.02	0.26	0.28	0.24	0.34	0.24	0.3	0.31	0.28	0.24	1										
11	Soci2	3.92	1.04	0.34	0.19	0.29	0.34	0.26	0.33	0.11	0.27	0.26	0.25	1									
12	Soci3	3.44	1.03	0.33	0.23	0.24	0.31	0.24	0.28	0.23	0.24	0.31	0.25	0.25	1								
13	Inn0	2.74	0.88	0.24	0.27	0.33	0.24	0.24	0.25	0.07	0.33	0.24	0.28	0.34	0.28	1							
14	Inn1	2.78	0.84	0.25	0.31	0.23	0.21	0.26	0.21	0.04	0.23	0.21	0.34	0.26	0.31	0.34	1						
15	Inn2	3.06	0.83	0.28	0.34	0.21	0.26	0.21	0.22	0.28	0.21	0.26	0.28	0.31	0.3	0.13	0.19	1					
16	Inn3	3.12	0.87	0.22	0.34	0.31	0.24	0.27	0.22	0.28	0.31	0.24	0.23	0.32	0.21	0.24	0.18	0.28	1				
17	Bas0	3.66	0.97	0.32	0.14	0.27	0.24	0.14	0.31	0.26	0.27	0.24	0.19	0.29	0.25	0.23	0.31	0.14	0.3	1			
18	Bas1	3.84	0.93	0.25	0.23	0.25	0.21	0.33	0.24	0.21	0.25	0.21	0.23	0.34	0.29	0.26	0.21	0.19	0.26	0.21	1		
19	Bas2	3.87	0.91	0.28	0.21	0.25	0.19	0.23	0.21	0.26	0.28	0.14	0.29	0.34	0.34	0.24	0.27	0.18	0.28	0.29	0.18	1	
20	Bas3	3.96	0.97	0.32	0.22	0.27	0.14	0.29	0.28	0.3	0.21	0.19	0.34	0.14	0.31	0.24	0.14	0.28	0.14	0.33	0.24	0.24	1
21	Vis0	3.02	1.04	0.25	0.22	0.26	0.21	0.34	0.22	0.2	0.24	0.17	0.31	0.23	0.31	0.21	0.33	0.26	0.15	0.23	0.21	0.27	0.27
22	Vis1	3.15	0.98	0.28	0.23	0.32	0.23	0.31	0.14	0.24	0.26	0.14	0.31	0.21	0.25	0.19	0.23	0.21	0.31	0.21	0.26	0.28	0.29
23	Vis2	3.42	0.94	0.33	0.26	0.31	0.2	0.31	0.19	0.23	0.27	0.26	0.23	0.22	0.27	0.14	0.29	0.26	0.27	0.31	0.24	0.29	0.31
24	Vis3	3.48	0.95	0.18	0.27	0.31	0.17	0.31	0.18	0.24	0.29	0.33	0.2	0.22	0.26	0.21	0.34	0.21	0.31	0.23	0.31	0.33	0.18
25	Lat0	2.68	0.88	0.34	0.14	0.26	0.25	0.32	0.16	0.28	0.27	0.24	0.17	0.23	0.32	0.23	0.31	0.24	0.25	0.22	0.29	0.34	0.31
26	Lat1	2.84	0.87	0.32	0.11	0.33	0.25	0.33	0.21	0.22	0.22	0.14	0.25	0.26	0.31	0.2	0.31	0.11	0.27	0.24	0.25	0.07	0.33

No.	Factor	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
27	Lat2	2.79	0.89	0.31	0.12	0.23	0.21	0.18	0.24	0.31	0.31	0.27	0.25	0.27	0.31	0.17	0.12	0.14	0.31	0.26	0.21	0.04	0.23
28	Lat3	2.81	0.84	0.26	0.15	0.34	0.19	0.25	0.18	0.12	0.32	0.26	0.32	0.34	0.13	0.2	0.31	0.19	0.34	0.21	0.22	0.28	0.21
29	Eff0	2.7	0.92	0.28	0.24	0.34	0.14	0.24	0.17	0.14	0.32	0.26	0.25	0.31	0.25	0.31	0.31	0.18	0.34	0.27	0.22	0.28	0.31
30	Eff1	2.64	0.89	0.26	0.21	0.28	0.17	0.25	0.18	0.19	0.34	0.27	0.28	0.27	0.21	0.34	0.32	0.16	0.28	0.14	0.31	0.26	0.15
31	Eff2	2.91	0.94	0.34	0.21	0.29	0.16	0.28	0.32	0.31	0.31	0.27	0.22	0.33	0.31	0.34	0.13	0.21	0.26	0.33	0.24	0.21	0.31
32	Eff3	3.14	0.98	0.26	0.23	0.27	0.28	0.23	0.31	0.3	0.18	0.27	0.32	0.28	0.13	0.14	0.24	0.34	0.21	0.23	0.21	0.26	0.27
33	Law0	1.02	1.2	0.21	0.26	0.21	0.23	0.26	0.33	0.12	0.34	0.14	0.25	0.26	0.23	0.23	0.15	0.24	0.26	0.21	0.26	0.21	0.31
34	Law1	2.03	1.02	0.22	0.27	0.23	0.21	0.24	0.34	0.21	0.32	0.11	0.28	0.21	0.28	0.21	0.23	0.21	0.21	0.31	0.24	0.24	0.16
35	Law2	2.07	0.97	0.33	0.22	0.19	0.24	0.24	0.29	0.24	0.31	0.12	0.27	0.21	0.32	0.22	0.21	0.26	0.24	0.25	0.19	0.31	0.21
36	Law3	2.16	1.14	0.32	0.22	0.23	0.24	0.26	0.24	0.24	0.24	0.28	0.33	0.31	0.27	0.14	0.31	0.24	0.25	0.28	0.26	0.27	0.24
37	e-P0	3.01	0.98	0.19	0.21	0.26	0.21	0.22	0.19	0.16	0.21	0.23	0.28	0.33	0.33	0.17	0.11	0.11	0.19	0.3	0.26	0.28	0.12
38	e-P1	3.42	0.97	0.27	0.31	0.24	0.27	0.22	0.17	0.11	0.11	0.31	0.24	0.27	0.21	0.26	0.21	0.22	0.27	0.14	0.29	0.28	0.3
39	e-P2	3.51	0.94	0.26	0.27	0.24	0.14	0.31	0.24	0.29	0.33	0.2	0.22	0.26	0.31	0.24	0.27	0.22	0.26	0.21	0.34	0.22	0.2
40	e-P3	3.77	0.97	0.26	0.14	0.31	0.21	0.25	0.19	0.27	0.24	0.17	0.23	0.32	0.27	0.24	0.14	0.31	0.25	0.21	0.33	0.24	0.22

No.	Factor	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
21	Vis0	1																			
22	Vis1	0.19	1																		
23	Vis2	0.11	0.34	1																	
24	Vis3	0.12	0.25	0.15	1																
25	Lat0	0.24	0.28	0.27	0.17	1															
26	Lat1	0.24	0.26	0.24	0.25	0.25	1														
27	Lat2	0.21	0.27	0.26	0.32	0.14	0.24	1													
28	Lat3	0.26	0.27	0.33	0.34	0.12	0.33	0.26	1												
29	Eff0	0.26	0.28	0.14	0.31	0.27	0.27	0.24	0.25	1											
30	Eff1	0.3	0.21	0.19	0.3	0.22	0.24	0.33	0.22	0.26	1										
31	Eff2	0.27	0.24	0.17	0.3	0.31	0.24	0.2	0.34	0.34	0.28	1									

No.	Factor	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
32	Eff3	0.24	0.26	0.14	0.31	0.32	0.32	0.26	0.16	0.31	0.24	0.21	1								
33	Law0	0.25	0.27	0.26	0.25	0.34	0.25	0.21	0.24	0.26	0.28	0.14	0.15	1							
34	Law1	0.18	0.27	0.25	0.26	0.22	0.24	0.22	0.29	0.3	0.21	0.19	0.16	0.25	1						
35	Law2	0.16	0.22	0.26	0.26	0.28	0.21	0.23	0.32	0.27	0.24	0.17	0.24	0.16	0.26	1					
36	Law3	0.2	0.31	0.29	0.19	0.32	0.33	0.24	0.25	0.34	0.26	0.14	0.17	0.27	0.24	0.21	1				
37	e-P0	0.24	0.29	0.33	0.2	0.22	0.26	0.12	0.11	0.34	0.32	0.34	0.27	0.14	0.17	0.14	0.18	1			
38	e-P1	0.28	0.27	0.24	0.17	0.23	0.32	0.25	0.21	0.23	0.34	0.29	0.26	0.22	0.26	0.21	0.34	0.21	1		
39	e-P2	0.22	0.22	0.14	0.25	0.26	0.31	0.28	0.14	0.29	0.34	0.34	0.24	0.23	0.32	0.23	0.31	0.24	0.25	1	
40	e-P3	0.29	0.34	0.31	0.13	0.21	0.26	0.33	0.24	0.21	0.21	0.23	0.21	0.21	0.31	0.24	0.24	0.31	0.32	0.22	1

1 = Adult Literacy (T0), 2 = Adult Literacy (T1), 3 = Adult Literacy (T2), 4 = Adult Literacy (T3), 5 = Internet (T0), 6 = Internet (T1), 7 = Internet (T2), 8 = Internet (T3), 9 = Social media (T0), 10 = Social media (T1), 11 = Social media (T2), 12 = Social media (T3), 13 = Innovation (T0), 14 = Innovation (T1), 15 = Innovation (T2), 16 = Innovation (T3), 17 = Basic services (T0), 18 = Basic services (T1), 19 = Basic services (T2), 20 = Basic services (T3), 21 = Importance of ICTs to government vision (T0), 22 = Importance of ICTs to government vision (T1), 23 = Importance of ICTs to government vision (T2), 24 = Importance of ICTs to government vision (T3), 25 = Latest technologies (T0), 26 = Latest technologies (T1), 27 = Latest technologies (T2), 28 = Latest technologies (T3), 29 = Government ICT efficiency usage (T0), 30 = Government ICT efficiency usage (T1), 31 = Government ICT efficiency usage (T2), 32 = Government ICT efficiency usage (T3), 33 = Laws relating to ICTs (T0), 33 = Laws relating to ICTs (T1), 34 = Laws relating to ICTs (T2), 35 = Laws relating to ICTs (T3), 37 = e-Participation (T0), 38 = e-Participation (T1), 39 = e-Participation (T2), 40 = e-Participation (T3)

Table 6.1 indicates that the correlation patterns between e-participation and variables were generally similar across time. The use of social media, ICT innovation, latest technologies, and government ICT efficiency characteristics appear more correlated with e-participation. This finding is noteworthy because it suggests that the governments with higher levels of ICT e-participation rates have citizens with high levels of social media usage and governments that use ICT more efficiently. In other words, the positive relationships indicate multiple ways that the government ICT implementation level can improve citizen e-participation.

Tests of Hypotheses

Part 1: Univariate Analysis

The LGM methodology provides researchers more modeling choices and versatility when evaluating growth over multiple measurements. To test this study's hypotheses, first, I examine whether the model fits the data and evaluate changes in the e-participation factors over time. Figure 6.1 shows an example of the univariate LGM model for literacy. The literacy data is measured across all countries to determine the intercept and slope over four time periods. The slope factor loadings are fixed to 0, 1, 2, and 3. This represents equal time periods between the data collection points. The intercept factor is fixed to 1 across all time periods. This makes sure the latent intercept has equal influence across all time periods.

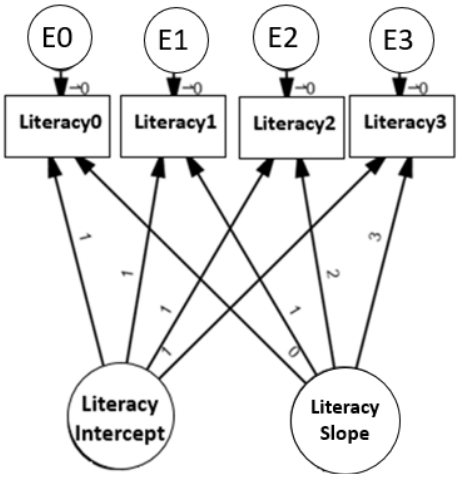

Figure 6.1: the LGM Univariate Model for Adult Literacy.

Tables 6.2 details the fit statistics for each of the LGM model. Table 6.3 present the latent intercept and slope and the covariance between the latent intercept and slope. I discuss these results in more detail in Chapter Seven.

The univariate models generally show good model fit as the CFI, NFI, and TLI are above 0.95 (Leal-Soto and Ferrer-Urbina 2017). The growth parameter estimates for e-participation factors are in Table 6.3. The mean intercept at the initial time is the average for each factor across all countries. The mean slopes are averages of rates of increasing or decreasing rates of change over T1-T3. All covariances between intercept and slope are significant except for Internet use.

My hypotheses expected increasing rates of change across e-participation factors over time. However, in the univariate models, some factors have decreasing rates, such as the implementation of basic services (-.071), availability of the latest technologies (-.042), government ICT efficiency (-.033), and ICT laws (-.006). This makes sense for some factors because not all variables related to e-participation would increase at an increasing rate. For example, there may be a greater lag time between the new ICT

availability or new laws for e-participation across countries. There is also not a significant covariance between the mean intercept and slope for Internet use, and all other covariances are significant.

The significance variances in the initial intercepts across all the factors are likely due to individual country differences, and some countries had higher/lower levels of perceptions about the factors at T0. All the change (slope) variances are significant except for adult literacy. Internet use, social media, and innovation show increasing rates for some countries, while basic services, availability, and government efficiency show decreasing rates. The significant and negative covariances (last column in Table 6.3) between the initial status and change for all factors, except Internet use, suggest the initial status is negatively associated with the decreasing trajectory. Countries with a higher initial status (mean) are likely to have a steeper negative trajectory across time, compared to countries whose initial status for each of the factors is lower. Internet use does not follow this trend of decreasing rates of change over time.

Table 6.2: Univariate LGMs: Model Fit Factors.

Factor	Model Fit				
	$\chi 2$	df	CFI	NFI	TLI
Literacy	14.60	5	.99	.99	.99
Internet	24.28	4	.99	.98	.98
Social Media	33.56	4	.97	.96	.96
Innovation	79.41	4	.96	.96	.96
Basic Services	15.47	4	.99	.98	.99
Gov. Vision	16.67	4	.99	.98	.98
Availability	11.92	4	.99	.99	.99
Gov. Eff.	4.92	4	.99	.99	.99
Laws	9.35	4	.99	.99	.99

Table 6.3: Growth Parameter Estimates of e-Participation Factors.

Factor	Initial Status - Intercept		Change - Slope		Covariance
	Mean	Variance	Mean	Variance	
Literacy	85.10***	319.346***	.308***	.311	-6.287***
Internet	37.95***	784.134***	2.16***	4.276***	2.175
Social Media	5.175***	.595***	.130***	.020***	-.046***
Innovation	3.207***	.821***	.169***	.025***	-.065***
Basic Services	4.351***	.779***	-.071***	.019***	-.026**
Gov. Vision	3.926***	.687***	-.002	.018***	-.030***
Availability	4.964***	.862***	-.042***	.014***	-.024**
Gov. Eff.	4.168***	.713***	-.033***	.021***	-.033***
Laws	3.928***	.957***	-.006	.020***	-.045***

***p < .001; **p < .01

Part 2: Multivariate LGM Analysis

After establishing the best model for each of the e-participation factors in Part 1, I did multivariate LGM to understand the relationship between each factor and the e-participation index (EPI) across time. I have created an example using the literacy factor to show the multivariate LGM model in Figure 6.1, with literacy analyzed along with the e-participation index in terms of their growth trajectories. In this model, all the slope and intercept factors covary to determine how they influence each other, or how the EPI covaries with each e-participation factor.

Table 6.4 displays the fit and the growth parameters (intercepts and slopes) for each LGM model. The covariances of the intercepts for each model between the factor and the e-participation index are all positive and significant. The results support H1-H9. The result shows that countries where the perceptions of each of these factors are higher also have a higher e-participation index score. In general, citizens' perceptions of the e-participation factors are significantly related to the e-participation index score at a point in time. This table is discussed in more detail in Chapter Seven. Table 6.5 is showing the

structural effects of the parameters on the e-participation index over time for every factor. This table is discussed in more detail in Chapter seven.

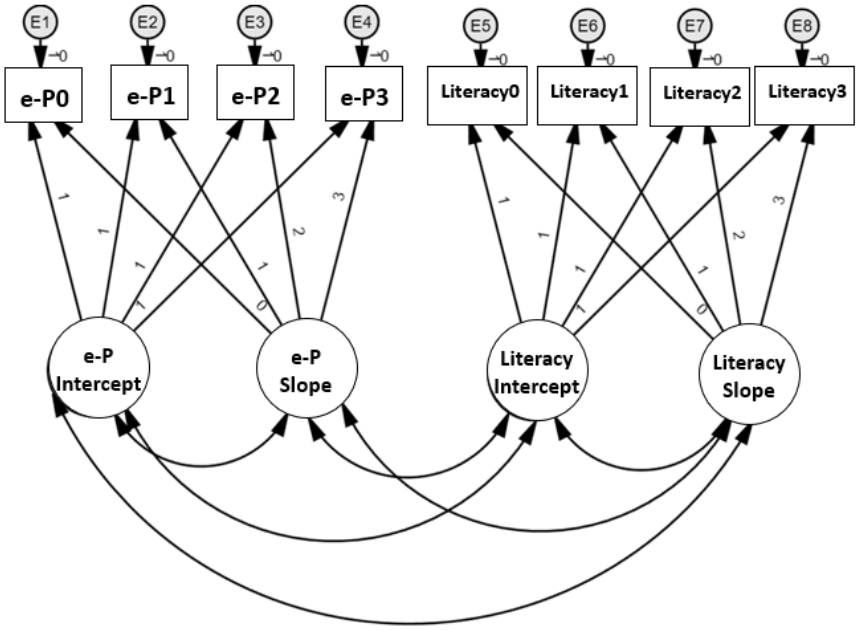

Figure 6.2: An Example of the Multivariate LGMs

Table 6.4: Multivariate LGMs: Effects of Factors with the EPI

Hypothesis	Model Fit				Means		Covariance
	$\chi 2$	df	CFI	NFI	Mean Intercept	Mean Slope	Intercept Covariance with EPI
H1a: Adult literacy	146.88	19	.95	.94	5.926***	.027***	.133***
H1b: Internet	139.95	20	.95	.94	2.655***	.152***	.297***
H1c: Social media	156.19	20	.93	.92	5.175***	.130***	.094***
H2a: Innovation	158.55	18	.93	.92	3.195***	.188***	.128***
H2b: Basic services	130.84	19	.95	.94	4.350***	-.068***	.123***
H2c: Gov. vision	146.09	20	.93	.92	3.926***	-.003	.070***
H3a: Latest technologies	129.48	20	.95	.94	4.965***	-.042***	.128***
H3b: Gov. eff.	125.02	20	.95	.94	4.168***	-.033***	.102***
H3c: Laws	133.57	20	.95	.94	3.925***	-.006	.142***

Table 6.5: Structural Effects of Growth Parameters on the EPI

Constructs		Intercept EPI	Slope EPI
Literacy	Intercept	.133***	-0.005
	Slope	-.003*	.001***
Internet	Intercept	.297***	0.008
	Slope	0.012	0.001
Social media	Intercept	.094***	0.005
	Slope	-0.003	0
Capacity for innovation	Intercept	.128***	0
	Slope	-.005*	0
Basic services	Intercept	.123***	0.001
	Slope	0.001	0
Government vision	Intercept	.070***	0.004
	Slope	0.001	0
Latest technologies	Intercept	.128***	0.005
	Slope	0	0
Gov. efficiency	Intercept	.102***	0.003
	Slope	-0.022	0
Laws	Intercept	.142***	0.003
	Slope	-.004*	0

Testing the Stigmergy Elements' Growth Trajectories

Table 6.6 details the results of examining the LGM parameters of models to understand the growth trajectory in terms of the three stigmergy elements: Agent, Sign, Environment. For example, the data for literacy, social media use, and Internet use were combined as components of the agent element in stigmergy theory. I evaluated the estimates of the means, variances, and covariances for each stigmery element to understand their growth trajectory as a part of the stigmergy process.

The result in Table 6.6 offers details on the essence of changes in the e-participation growth trajectory in terms of agent, sign, and environment. The agent's initial mean status was 3.43, sign(s) was 3.92, and the environment was 3.79. These are the average levels of the e-participation mechanisms (agents, signs, environment) at Time

= 1. The variances in the initial status for an agent, sign, and environment were statistically significant (0.53, 0.79, and 0.62, respectively), showing the means for each vary among the countries. The change variances were statistically significant (0.23, 0.38, and 0.32, respectively), showing the rate of change also varies among the countries. The last column comparing the initial status (IS) covariance and the change (CH) are all significant. This means these stigmergic related e-participation mechanisms displayed positive and significant growth over the T1-T3. Interestingly, signs had the highest initial mean level and largest positive growth trajectory. The environment played a vital role in the e-participation phenomenon, with agents showing the least change on average over time.

Table 6.6: Changes in the e-Participation Stigmergic Mechanisms

Variables	Initial Status (IS)		Change (CH)		Covariance (IS-CH)
	Mean	Variance	Mean	Variance	
Agent(s)	3.43***	0.53***	0.31***	0.23***	0.22***
Sign(s)	3.92***	0.79***	0.48***	0.38***	0.39***
Environment	3.79***	0.62***	0.44***	0.32***	0.37***

Testing E-Participation in LGMs for Developed/Developing Countries

First, I conducted a preliminary analysis comparing the data across developed and developing countries (see Appendix A Table A.2 for more detail); both types of countries have reported e-participation capabilities. There were differences in the means for all the e-participation factors when viewed by a developed or developing country, as shown in Table 6.7. These differences might be consequential to explain the differences in e-participation growth in developed vs. developing over time. Moreover, it is understandable that developed nations with a larger economy can devote more resources

to ICT investments. Logically, ICT investment would positively impact government ICT usage, which would improve the government ICT efficiency in developed countries. In fact, laws relating to ICT have a higher mean in developed countries. It could be that more ICT investment and usage reveal issues related to ICT activities, and governments may respond by enacting additional laws to protect beneficiaries.

I did t-tests to determine if the means for each factor is statistically different between the two groups. Results show significant differences in all of the e-participation factors between the two groups. The comparison of Government Vision between developed and developing countries in T1 and T2 were slightly above the p = .05 level.

Table 6.7: Developed / Developing Countries data

	Developed		Developing			
Constructs	Mean	S.D.	Mean	S.D.	t-statistic	Sig.
Literacy (T0)	98.325	2.364	80.644	18.770	-5.702	0.000
Literacy (T1)	98.355	2.282	81.088	18.325	-5.704	0.000
Literacy (T2)	98.396	2.221	81.246	18.260	-5.686	0.000
Literacy (T3)	98.020	3.716	82.819	17.762	-5.157	0.000
Internet (T0)	70.667	17.819	25.847	20.452	-11.892	0.000
Internet (T1)	73.306	16.039	28.603	21.827	-11.451	0.000
Internet (T2)	75.866	15.505	31.841	23.695	-10.554	0.000
Internet (T3)	76.493	15.218	33.606	24.122	-10.144	0.000
Social media (T0)	5.753	0.572	4.872	0.752	-6.516	0.000
Social media (T1)	5.898	0.475	5.116	0.690	-6.397	0.000
Social media (T2)	6.017	0.432	5.268	0.702	-6.114	0.000
Social media (T3)	6.111	0.412	5.293	0.714	-6.605	0.000
Innovation (T0)	4.087	0.995	2.889	0.637	-8.491	0.000
Innovation (T1)	4.146	0.970	2.973	0.613	-8.593	0.000
Innovation (T2)	4.339	0.870	3.344	0.576	-7.914	0.000
Innovation (T3)	4.499	0.831	3.587	0.613	-7.124	0.000
Basic services (T0)	5.119	0.726	4.136	0.783	-6.729	0.000
Basic services (T1)	5.007	0.765	4.011	0.778	-6.770	0.000
Basic services (T2)	4.903	0.777	3.973	0.779	-6.282	0.000
Basic services (T3)	4.899	0.763	3.934	0.785	-6.507	0.000
Gov. vision (T0)	4.103	0.758	3.799	0.829	-1.976	0.050

Constructs	Developed		Developing		t-statistic	Sig.
	Mean	S.D.	Mean	S.D.		
Gov. vision (T1)	4.137	0.736	3.867	0.827	-1.776	0.080
Gov. vision (T2)	4.140	0.740	3.855	0.841	-1.833	0.069
Gov. vision (T3)	4.134	0.707	3.790	0.826	-2.267	0.025
Latest technologies (T0)	5.863	0.757	4.645	0.765	-8.398	0.000
Latest technologies (T1)	5.836	0.741	4.639	0.763	-8.310	0.000
Latest technologies (T2)	5.754	0.702	4.575	0.785	-8.105	0.000
Latest technologies (T3)	5.746	0.675	4.493	0.764	-8.879	0.000
Gov. efficiency (T0)	4.594	0.767	4.002	0.822	-3.853	0.000
Gov. efficiency (T1)	4.572	0.716	4.000	0.813	-3.813	0.000
Gov. efficiency (T2)	4.518	0.710	3.957	0.825	-3.695	0.000
Gov. efficiency (T3)	4.488	0.701	3.898	0.826	-3.896	0.000
Laws (T0)	4.845	0.803	3.590	0.822	-8.082	0.000
Laws (T1)	4.806	0.755	3.637	0.818	-7.660	0.000
Laws (T2)	4.742	0.683	3.617	0.847	-7.314	0.000
Laws (T3)	4.733	0.669	3.589	0.822	-7.650	0.000
e-Participation (T0)	0.452	0.237	0.165	0.162	-8.238	0.000
e-Participation (T1)	0.436	0.278	0.236	0.237	-4.238	0.000
e-Participation (T2)	0.436	0.278	0.243	0.243	-4.020	0.000
e-Participation (T3)	0.629	0.222	0.401	0.245	-5.012	0.000

Then, I considered the different types of countries in terms of developed or developing to understand the different results related to the stigmergy processes of Agent, Sign, and Environment. More specifically, to understand the statistical equivalence between the two types of countries at each point of measurement, I found some differences. Table 6.8 details the results of the LGMs for the stigmergy elements. I will discuss the results in the table in Chapter Seven.

Table 6.8: LGMs for Stigmergy Models by Developed/Developing Countries

	Model Fit					Model Results Regression Weights			
	$\chi 2$	df	CFI	NFI	TLI		Intercept Est	CR	Slope Est	CR
Agent	255.39	67	.96	.95	.96	Literacy	17.692***	5.946	-.408*	-2.261
						Internet	45.47***	12.544	-.850*	-1.942
						Social Media	.805***	6.245	-.016	-.667
Signs	388.43	63	.93	.92	.92	Innovation	1.215***	8.874	-.104***	-3.498
						Basic Services	.926***	7.669	.003	.114
						Gov. Vision	.307*	2.007	.011	.549
Environment	321.55	64	.94	.93	.93	Latest Tech	1.171***	7.945	.016	.877
						Gov. Efficiency	.552***	3.571	.013	.538
						Laws	1.207***	8.526	-.027	-1.092

CHAPTER SEVEN

Discussion

This study's findings from the e-participation theoretical model (Figure 3.1) are discussed in this section, specifically factors that contribute to the growth trajectory of e-participation. The first collection of findings explains the relationship between e-participation and the factors in this study. The second part discusses the stigmergic mechanism (agent, sign, and environment) that facilitate e-participation formation and its growth trajectory.

e-Participation Factors

The objective of this study was to answer the main research questions: 1) What factors contribute to the growth trajectory of e-participation? 2) How is the stigmergic mechanism involved in e-participation growth? In this study, I examined the growth trajectory of nine e-participation factors in 147 countries across 2014 to 2020. The results show interesting findings for all of the tested factors. First, I discuss the support for the hypotheses in terms of the relationship of each factor with the e-participation index. Second, I discuss stigmergy theory in terms of how agent, sign, and environment operate in developed and developing countries and their e-participation growth trajectory.

Adult Literacy

The LGM findings indicate that citizens' literacy is significantly related to the e-participation index (EPI) score. In Table 6.4, the means intercept of literacy is 5.926 ($p < .001$) at the initial status, which in general, is relatively high across the countries in the dataset given that a majority of the countries (113) are characterized as developing. Literacy was converted from a percentage to a 1-7 scale for better interpretation and comparison in this table. The mean for literacy was 85.11 percent and significant in the univariate LGM, and the growth is on average .308 between the time points. Literacy also has the highest mean across all the factors tested, and literacy shows a positive slope (.027, $p < .001$). This means that for some countries, literacy increased at a faster rate over the time period.

The covariance of the intercepts for literacy and the EPI are significantly and positively associated (.133, $p < .001$). This means when a country's adult literacy is higher, the EPI is also higher at a given moment in time. Table 6.5 gives more insight into significant growth parameters related to literacy. For example, for countries beginning with a higher EPI, literacy has a negative trajectory of change (-.003, $p < .05$) over time (EPI Intercept – Literacy Slope). These countries' rates of change in literacy over time were not as great as the countries with an initial lower EPI. One explanation may be that when a country already has a high EPI, their adult literacy is already high, so there is little room for growth in literacy compared to countries where literacy is low.

Additionally, in this study's findings (Table 6.5), the slope for adult literacy has a significant and positive (0.001, $p < .001$) relationship with the trajectory (slope)

of e-participation over time. The growth trajectory of the EPI is positively associated with the rate of increase in adult literacy. Literacy is fundamental to nations' modernization efforts and knowledge and is likewise significant to e-participation.

> *Finding: Adult literacy in a country is positively associated with the EPI at a given moment. Some countries' literacy increased at a faster rate as the EPI increased. For countries with high initial EPI, literacy has a lower growth trajectory.*

The scatterplot shows the relationship between the EPI and literacy across the dataset. The data indicate that e-participation has a moderately positive correlation with the indicator adult literacy. Estonia, Morocco, and Latvia are among the countries in Figure 7.1 upper right quadrant, indicating that they have strong scores for adult literacy and high EPIs. Chad, and Mauritania, on the other hand, are among the countries in the lower left corner of the chart, indicating that they have low values for adult literacy, and low EPIs.

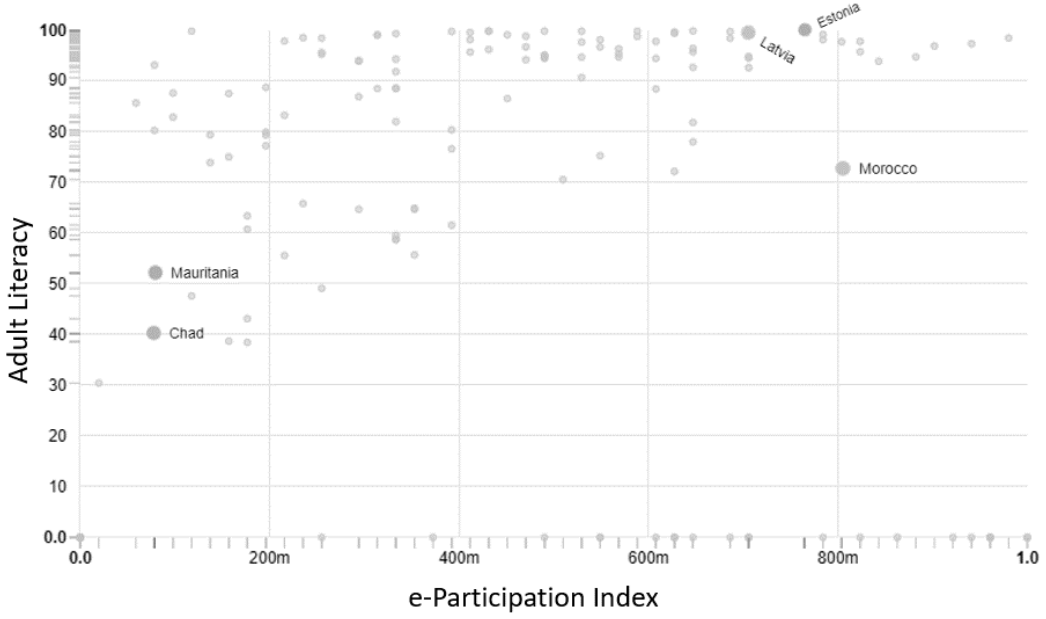

Figure 7.1: The Relation between e-Participation and Adult Literacy.

Internet Usage

This study model found that Internet usage is significantly related to the e-participation index (EPI) score. Referring to Table 6.4, the mean for Internet use at initial status is equal to 2.655 ($p < .001$), keeping in mind that the Internet is a service that is available in both developed and developing nations. On a 1-7 scale, Internet use appears low across the countries. It is also the lowest mean of all the factors from 2014-2020. However, it has a large average slope (.152, $p < .001$) between the time periods, showing that Internet use has an increasing growth trajectory over the time period.

Overall, Internet usage has a high covariance of the intercepts, and it is significantly and positively associated with the mean status of EPI (.297, $p < .001$), which is the highest significant intercept covariance with EPI. When a country's Internet use is high, the EPI is also high at a given moment in time. As shown in Table 6.5, both the slope-slope covariance (.001, ns) and slope-EPI intercept covariances (.012, ns), although positive, are not significant. There is no evidence that countries with higher EPI are different from countries with lower EPI in terms of the rate of growth of Internet use across the time period. This might mean Internet use may have a more extended time period to show visible growth in use, or lag time, that is greater than the time period in this study. For example, it takes many years for the physical infrastructure of the Internet to develop in countries, especially in developing countries. The range of the data tested was over only seven years, and the mean Internet use was only 2.655, on a 1-7 scale, which is low. Overall, countries' Internet use has an increasing trajectory over the time period.

Finding: Countries with a higher/lower EPI have higher/lower Internet use. Internet use has a positive growth rate across the time periods.

In today's world, the numbers of people who have access to the Internet are increasing rapidly due to the tremendous amount of money governments put into their ICT infrastructure (Czaja and Lee 2003). However, this growth in Internet use is likely more rapid in countries with the physical infrastructure already in place. Government ICT investments are dedicated to building the ICT infrastructure, such as the Internet, to improve services to citizens and encourage e-participation. According to International Telecommunication Union (ITU) data statistics, Internet availability continues to expand globally, with 4.1 billion people (or 53.6 percent of the global population) now online[1]. Alternatively, 3.6 billion people are still without Internet access. According to a new study from Grand View Research Inc.,[2] the global ICT investment in the government market is projected to hit USD 654.73 billion by 2025. Governments are investing heavily in their country's ICT capabilities.

e-Participation denotes a type of citizen control; citizens are encouraged to take on obligations and initiatives and work with governments in a two-way relationship. This is analogous to the Srivastava et al. (2016) discussion of e-participation in terms of three broad aspects: e-information accessibility, e-consultation, and e-decision-making. e-Participation uses a variety of ICT resources to achieve a variety of goals, including providing citizens with information (e-information availability)[3], welcoming citizens' views for deliberative and

[1] Measuring Digital Development Facts and Figures, 2019

[2] https://www.grandviewresearch.com/

participatory processes (e-consultation)[4], and incorporating citizens' feedback into decision-making (e-decision-making)[5]. Internet use by citizens is critical to achieving the government's e-participation goals.

Current data shows that several countries, including Italy, Spain, and the USA, have increased ICT investment as their central governments promote e-government services[6] (see Figure 7.2). This will continue to increase Internet use among the citizens. For the years 2014 to 2020, the United States has the most stable year-on-year average growth rate of 1.24 percent, while the United Kingdom has the highest year-on-year average growth rate of 4.75 percent among the countries studied. Furthermore, Spain has an average growth rate of 2.29 percent, while Switzerland has the lowest year-on-year average growth rate of 2.14 percent among the countries in Europe.

[3] e-Information: Enabling participation by providing citizens with public information and access to information without or upon demand.

[4] e-Consultation: Engaging citizens in contributions to and deliberation on public policies and services

[5] e-Decision-making: Empowering citizens through co-design of policy option and co-production of service components and delivery modalities.

[6] www.un.org

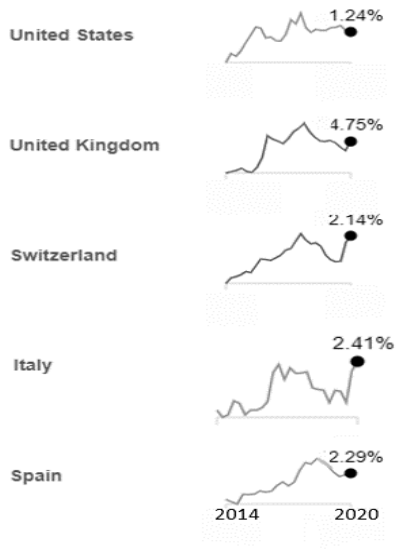

Figure 7.2: Government ICT Investment Average Growth Rate.

ICT investment and greater Internet use can transform the public sector by enhancing its efficiency, effectiveness, transparency, inclusiveness, supporting access to public services, and most importantly, support of e-participation (Amegavi et al. 2018; Petkovics 2018). Overall, ICT investment increased in all countries, although there were some growth rate variations over time. For example, the Asia & Pacific region witnessed phenomenal growth over the last few years, as most countries increasingly embraced innovation and utilized ICTs to deliver services and engage people in e-participation[7]. In Asia, ICTs investment opened up entirely new avenues for e-participation, both in terms of participation platforms and the outcomes of participatory activities. This is especially true for goods or services that depend on the decentralized aggregation of individuals and voluntary inputs from many citizens.

[7] Asia Development Bank

e-Participation can enhance government transparency by empowering citizens to gain access to new power outlets and lower public engagement barriers in decision-making (Medaglia 2012; Zolotov et al. 2018). Without the necessary ICT infrastructure to support Internet use, any e-participation initiative would be difficult to implement. As a result, one of the most significant obstacles to e-participation adoption in Sub-Saharan Africa is the lack of adequate ICT infrastructure (Bagui et al. 2016). Significant obstacles to e-participation, in addition to inadequate ICT infrastructure, include citizens financial inability to buy a connecting device (PC, tablet, smartphone, etc.), the ineffectiveness of promotions to raise awareness about available e-participation initiatives, inappropriate ICT governance frameworks, and officials' and citizens' lack of skills (Cloete 2012; Mitrovic et al. 2014; Ochara and Mawela 2015). The combination of these barriers poses a barrier to citizens utilizing e-participation services. However, the results in Table 6.4 suggest that when the ICT infrastructure supports citizens' Internet use, then e-participation will also increase.

Social Networks

According to the LGM findings, social networks or the use of social media has a substantial relationship with the e-participation index (EPI) score. The mean intercept of social networks at the initial status is 5.175 in Table 6.4, which means the citizens in the countries in this sample of nations generally use social networks. Social networking also has a significant positive average rate of growth, slope equals .130 ($p < .001$), between the time period for the countries.

In Table 6.5, the covariance of the intercepts for social media and the EPI is strong and positively associated (.094, $p < .001$). This means that countries with a

higher EPI also exhibit a higher social media presence at a point in time, which is important for e-participation.

> *Finding: Countries with higher/lower social networking among citizens have a higher/lower EPI. Social media has a positive growth rate between the time periods.*

Social media is an emerging tool to support e-participation in various ways by enhancing services to citizens, organizations, and government employees (Abdelsalam et al. 2013; AbuJarour and Krasnova 2017). Social media has the potential to increase transparency and community engagement, as well as assist public sector organizations in strengthening their internal operations.

With the increased use of the Internet and social networks, and greater adult literacy in general, e-participation increases, as the findings in Table 6.4 show. These factors help engage citizens in public policy decision-making. Although e-participation programs have been developed over the last two decades, many of these have struggled to achieve a sufficient public participation level in policy decision-making (Charalabidis et al. 2014; Sæbø et al. 2011; Macintosh et al. 2009). Even after integrating social media networks which are known to improve citizens' engagement, knowledge sharing, and distribution, the problem of increasing e-participation persists. For example, the data indicate Cameroon has the highest average annual growth rate of 4.83 percent in social media usage. Cameroon has always perplexed the international community in terms of its economic potential versus its level of growth. Despite its ICT infrastructure, the country still lags behind in terms of e-participation. In 2018, a case study about Cameroon showed that e-participation based on Web 2.0 and social media networks could provide new opportunities for

citizens to practice participation activities to support good governance (Bawack et al. 2018).

A scatterplot of the data is shown in Figure 7.3 to illustrate the discrepancy between the EPI and social media. Lesotho and Chad are among the countries in the scatterplot's upper left, indicating lower social media usage rates and lower associated global e-participation rankings. The UAE, Norway, the United States, and Iceland, on the other hand, are among the countries in the scatterplot's lower right corner showing high levels of social media usage and higher e-participation rankings. The UAE has a social media value of 6.580, placing it in the top 10% of countries for social media usage, which is remarkable because the UAE is considered a developing country. Also, the UAE has the highest social media usage level value among the developing countries. The plot shows nations have made significant progress in their use of social media and the development of strategies to engage citizens in e-participation related matters through social media. Nearly all countries reported a social media usage higher than 4, on a 1-7 scale. On the other hand, a few others are not sufficiently engaged, or their social media activity is inadequate.

The data and findings from the LGM analyses indicate that the use of social media is promising for e-participation. Countries ranked lowest in e-participation are also lowest in social media use. Whereas the US and Norway with high e-participation rankings are countries with the highest social media use. The findings in Table 6.4 support this with countries' high/low EPI index significantly associated with a high/low social media use at a given point in time.

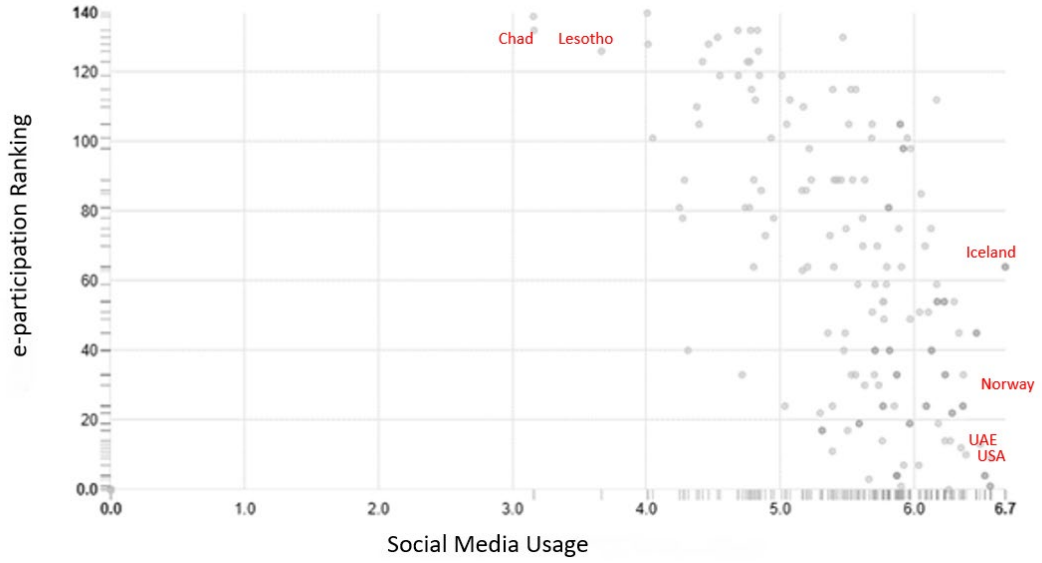

Figure 7.3: The Relationship between e-Participation and Social Media Usage.

Capacity for Innovation

This study also provides important information regarding the nations' capacity for innovation and how the changes in EPI are affected by this factor. The findings are shown in Table 6.4. The mean initial status of capacity for innovation was 3.195, with a mean slope of (.188, $p < .001$). Because the majority of countries in the dataset are classified as developing (113), it is not surprising the mean of innovation capacity is lower across the countries. However, the significant positive slope for the factor means the capacity for innovation across the countries increased linearly over the time periods.

The covariance of the intercepts for innovation and the EPI was positive and significant (.128, $p < .001$). Capacity for innovation is another e-participation factor significantly associated with the EPI. Also, as shown in Table 6.5, the covariance of the innovation slope and the EPI intercept is negative and significant (-.005, $p < .05$).

This means that countries with a higher EPI will demonstrate a slower growth rate of innovation capacity, compared to countries with lower EPI.

> *Finding: Countries with higher/lower EPI is significantly associated with a higher/lower innovation capacity. Countries with higher initial EPI exhibit lower growth rates for innovation capacity.*

The results suggest that greater capacity for innovation may be an advantage for increasing e-participation. For example, a country's citizens and other stakeholders are expected to participate in public initiatives and decision-making processes through e-participation, contributing their opinion, information, and experience in far greater detail than traditional participation would allow. Traditional participation implies public involvement that is not supported by ICT in this sense. However, innovations in ICT apps enables public authorities to resolve conventional engagement issues (Abdelsalam et al. 2013; AbuJarour and Krasnova 2017; Czaja and Lee 2003). These may be related to involving many citizens, minimizing expense and time in complex decisions, minimizing the delay between intervention and outcomes, and resolving knowledge imbalances with citizens. However, as Tables 6.4 and 6.5 show, the capacity for innovation can improve e-participation outcomes.

Innovation in ICT tools, for example, has the advantage of allowing government agencies to digitally capture and store participants' ideas and feedback in a central database. Consequently, the collected data can be passed between the different stakeholders effortlessly to increase the effectiveness of e-participation processes.

This study's results support the idea that governments with a higher capacity for innovation have a higher demand for e-participation. Additionally, for countries

starting out lower in e-participation, innovation has a greater impact on their growth trajectory. However, innovations come with their own set of obstacles. For example, ICT innovations may not be an effective tool to help marginalized people gain access to the policy-making process for many reasons. Also, the most educated citizens may not be familiar with or comfortable with the most recent innovations, and language barriers may prohibit others from successfully using innovations. Second, developing and maintaining successful ICT innovation is expensive, and they may not yield the desired results. For example, collecting citizen data and information and making it available does not imply increased effectiveness for policy decision-making or citizen participation in the process. In reality, if not done correctly, the design and implementation of ICT innovations to help e-participation outcomes can backfire.

The security of digital information is a major concern with ICT innovations. Transparency in government requires documents that are trustworthy, accessible, and well-maintained. Without a system for information governance, innovations to enhance e-participation can lead to citizens being misled and misinformed rather than empowered. The first move is to raise government awareness that maintaining information integrity and access over time in a digital environment necessitates a well-defined legal and regulatory system as well as a new set of skills. To keep governments accountable, digital documents must be in a usable format and secure from degradation over time. To summarize, using ICT innovations may face obstacles to increase citizens' e-participation. Technology can fall out of favor if it generates data that is not then used. A country's innovation strategies need long-term, listening-based, citizen-focused approaches to overcome barriers and facilitate e-participation.

Access to Basic Services

Table 6.4 shows the mean intercept for citizen's access to basic government services using ICT is above the midpoint (4.350) with a significant negative slope (-.068, $p < .001$). This indicates countries with higher access to basic services at the initial time generally have a decreasing rate of growth in basic service access over time. While I expected increasing rates of change across e-participation factors over time, this is not the case with basic service access. This finding should be investigated further. It might be that citizens already having higher access to basic services also have a demand for even more services, compared to citizens in countries with low access. So, they perceive their access could be improved, even though it is relatively high. Additionally, there is a significant positive covariation (.123, $p < .001$) of the EPI intercept with the basic service intercept. This shows that in general, when a country has a higher EPI, the access to basic services is also higher at a given point in time.

> *Finding: Countries with higher/lower EPI have a higher/lower access to basic services. Countries with a higher score for basic services have a lower growth rate across the time period.*

Importance of ICT to Government Vision

Table 6.5 shows a significant mean intercept for ICT importance to government vision across the countries in the dataset at 3.926, below the mid-point of 4. However, the slope of this factor is not significant (-.003, $p > .05$), indicating it has a flat trajectory over the 2014-2020 time period. While the LGM results show there is no growth in this factor, countries with higher/lower EPI also exhibit a higher/lower

score for the importance of ICT to government vision. The intercept covariance estimate is significant and positive (.070, $p < .001$).

This factor refers to how citizens believe that government has a vision going forward in using ICT. It is critical to understand citizens' perception of how government intends to use ICTs to increase their country's competitiveness. Because ICT can improve e-participation, it is important to understand if citizens believe their governments are working for them. This may not be true. For example, although developing countries invest in infrastructure and seek new ways to link their citizens to information and ICT, there is an unexpected lack of access by citizens (Czaja and Lee 2003; Petkovics 2018; Phang and Kankanhalli 2008). While the ICT infrastructure investment rate in North America (79.8%) and Europe (62.3%) are relatively high, other regions of the world struggle to build an infrastructure to link their citizens to online information [8]. When citizens do not see progress, they are likely to believe their nation lacks vision, which may hinder e-participation. For example, a nation may promote ICT use, and citizens in large cities are engaged, but they may fail to provide it in remote regions and suburbs, which is a severe problem in developing countries. Low belief in a country's vision is associated with lower e-participation. When citizens see their governments making progress, their belief in government vision will increase.

> *Finding: Countries with higher/lower EPI have a higher/lower perception of the importance of ICT in government vision. Countries with a higher score for importance of ICT to government vision have a lower growth rate across the time period.*

[8] www.un.org

Availability of Latest Technologies

The availability of latest technology refers to citizens' perceptions of the technology they use compared to the latest technologies available to citizens. Table 6.4 shows the mean intercept for availability of latest technologies factor is above the midpoint (4.965) with a significant, negative slope (-.042, $p < .001$). This indicates countries with higher latest technologies at the initial time generally have a decreasing growth trajectory over time. While I expected increasing rates of change across e-participation factors over time, this is not the case with availability of latest technologies.

This finding is interesting and should be investigated further. It might be due to the fact that citizens globally always look to have access to latest technology, that is, there is an ongoing demand for new technology, compared to citizens in countries with less access to latest technology. Or it may be the availability of the latest ICT shows a decreasing rate of change over time due to a lag time. For example, when a government has implemented new mobile apps, or new electronic services platforms (e.g., website or blog), there is an evaluation time of the implementation before another is begun. The time period capturing citizen perceptions in the data may be too short.

It makes sense that the government would provide access to latest ICT to meet citizen demand, and if the demand is not there, will not continue. Additionally, there is a significant positive covariation of the EPI intercept with the availability of latest technologies intercept (.128, $p < .001$). This shows that in general, when a country

has a higher EPI, the availability of latest technologies is also higher at a given point in time.

> *Finding: Countries with higher/lower EPI have a higher/lower perception of the availability of latest technologies. Countries with a higher score for availability of latest technologies have a lower growth rate across the time period.*

In today's global digital culture, it is widely acknowledged that in an e-government environment – whether global or local – ICT provides many opportunities for the public sector to realize gains and improve their engagement in democratic decision-making. The availability of the latest ICT technologies would facilitate engagement with citizens and contribute to the development of new electronic services. For benefits to be realized, the knowledge space must be accessible and well-organized to encourage the provision of the latest technologies across the public sector to encourage long-term and ongoing growth in a participatory society. In general, the advantages of e-participation, as a result of improved availability of current ICT technologies, can be measured in terms of increased productivity (e.g., cost savings or prevented costs), effectiveness (e.g., increased citizens gains and opportunities), and good governance (e.g., gain in trust of citizens due to de-bureaucratization).

Government ICT Efficiency

Government ICT efficiency is a factor that refers to the extent that the government's use of ICTs improves the quality of government services to the population (Bagui et al. 2016; Bertot et al. 2010). That is, citizens perceive their government is efficient in its use of ICT to provide citizen services. Table 6.4 shows

the mean intercept for government efficiency factor is above the midpoint (4.168, $p < .001$) with a significant negative slope (-.033, $p < .001$). This indicates countries with higher citizen perceptions of government ICT efficiency at the initial time generally have a decreasing growth trajectory over time in this perception. While this study expected that the e-participation factors would have increasing growth trajectories, this is not the case with government ICT efficiency. However, the intercept covariances are significant and positive (.102, $p <.001$), showing a country with a higher EPI will have a higher perception of government efficiency at a point in time.

> *Finding: Countries with higher/lower EPI have a higher/lower government ICT efficiency. Countries with a higher score in government ICT efficiency have a decreasing growth trajectory across the time period.*

Citizen belief in ICTs for increasing government efficiency is associated with e-participation. e-Participation, which blends the advantages of ICT support for efficiency, transparency, and automated documentation, is a promising way of engaging citizens. For example, incorporating ICT into participation has the benefit of allowing public authorities to digitally capture and store digital communications from participating citizens in a central database. Government efficiency is increased when the collected data can be seamlessly passed between the different ICT tools and processes. Online consultancy services on a national level are well-established and widely available in many countries (Avgerou and Bonina 2020; Ekelin 2007). These are an example of the use of ICT to increase government efficiency that citizens will see in their lives. Other examples of government efficiency with ICT that are visible to citizens include digital documentation and digital signatures, to name a few (Carter and Bélanger 2005; Poser et al. 2019). The analysis results suggest that the more

citizens believe their government is using ICT in a competent and useful way to help its citizens, the more citizens are likely to engage in e-participation.

ICT Laws

In Table 6.4, citizens' perception of the ICT laws across the countries has a mean of 3.925 with a negative, non-significant slope (-.006, $p > .05$). The non-significant slope factor indicates that perceptions of ICT law remain stable across the time period for the countries in the dataset. The significant covariance of the EPI intercept and the intercept for ICT laws (.142, $p < .001$) means that countries with higher EPI also have higher perception scores regarding their country's ICT laws.

Table 6.5 shows a significant negative covariance (-.004, $p < .05$) between the EPI intercept and the slope of the ICT laws factor. This means for countries starting out with higher EPIs, they have a negative rate of growth over time compared to countries starting out with lower EPIs.

> *Finding: Countries with higher/lower EPI have a higher/lower perceptions of ICT laws at a given time. Some countries' ICT laws increase at a faster rate as the EPI increased. For countries with high initial EPI, ICT laws has a lower rate of growth.*

The stable slope for the ICT laws factor over time may be due to the time element in terms of the time it takes to legislate, enact, and enforce ICT laws. Citizens may believe not much has changed over 2014-2020, particularly in countries that already have a high EPI.

Summary of e-Participation Factors

In general, the results show a significant positive association of each of the factors with the EPI as hypothesized. Additional insights are gained by evaluating the univariate LGM results. For example, Table 6.3 shows that the means of each factor at the initial time point, and their variances are significant. This shows the countries in the dataset are not similar, they tend to vary significantly from the mean.

Table 6.3 also shows a non-significant univariate slope for perceptions of government vision and laws, which is a flat growth trajectory over the time period. This differs by country as the slope variances are significant. While some factors have positive slopes (Internet use, social media, innovation capacity) the variation among countries is significant. The output also has some negative slopes (basic services, availability, efficiency) showing a general negative growth trajectory. Again, there is significant variation at the country level. This makes sense because not all e-participation related variables would grow at the same rate. Take the access to basic services as an example. Any new online app takes time to be superior (e.g., fix the website issues, relace new app versions, or/and update the ap). The access to ability of the basic services through the ICT takes time, and as the covariance shows (-.026, $p < .01$), countries with higher basic service scores will have a negative growth trajectory.

Stigmergy Theory: Agent, Sign, and Environment

As the LGM analyses suggests, the countries differ significantly in terms of the factors. Countries are not homogeneous, and the e-participation factors are entwined and affect each other across time. Each of the factors is entangled with the

others. The countries differ in terms of their initial status (T0) for each factor and their growth trajectory. I used the stigmergy theory to group the factors by their categorization as agent, sign, or environment to determine the nature of each stigmergy element and its growth over time (Table 6.6). Then, I did latent growth analysis to evaluate the stigmergy elements by comparing two groups (Table 6.7) and (Table 6.8). The developed countries and the developing countries as determined by the United Nations (see Appendix Table A.2). The objective is to understand how the factors complement each other in a stigmergic mechanism model. Figure 7.4 shows the growth trajectory of the EPI data for developed and developing countries.

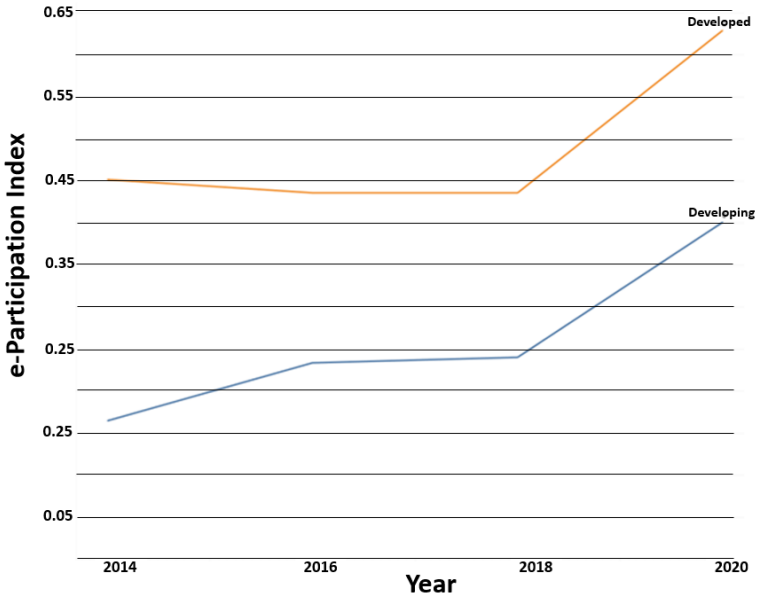

Figure 7.4 The Growth of e-Participation in Developed and Developing countries.

Table 6.6 shows the LGM results for Agents, Signs, and Environment. The three stigmergy elements have significant means and variances and significant positive slopes and variances. The covariances between the initial mean and slope are

also significant and positive. Signs has the highest mean (3.92) and significant variance across the countries. Over the time period, the growth trajectory of signs is greatest with a mean slope of 0.48 ($p < .001$). Agents has the lowest mean score (3.43) and lowest mean rate of increase (slope = .31, $p < .001$). The covariance column shows similar results for each element. Countries with the highest mean for each element are associated with the greatest change over time for each element.

Table 6.8 shows the LGMs for the three stigmergy models comparing developed and developing countries. The output is from developed countries' point of view. In the agent category, the data for the developed countries started off with significantly higher levels of adult literacy (17.692, $p < .001$) and Internet usage (45.147, $p < .001$), as expected, as well as significantly higher levels of social media usage (.805, $p < .001$) compared to developing countries. Additionally, adult literacy (-.408, $p < .05$) and Internet usage (-.850, $p < .05$) have significantly decreasing rates of change over time for the developed countries. These factors advance at a lower rate compared to the developing countries. In the agent category, social media shows a flat rate of change for developed nations over time.

Signs and environment models for developing countries show higher perceived levels for innovation (1.215, $p < .001$), access to basic services (.926, $p < .001$), ICT in government vision (.307, $p < .05$), availability of latest technologies (1.171, $p < .001$), government efficiency (.552, $p < .001$), and ICT laws (1.207, $p < .001$). Results also show perceptions of innovation (-.104, $p < .001$) has a significant decreasing slope over time for the developed countries. Countries that start out high on innovation have lower rates of growth over time compared to the developing

countries. There was no significant difference in the changes in perceptions of developed and developing countries over time concerning the environment factors.

The results suggest that some aspects of agents, such as literacy and Internet use, may peak for developed countries compared to developing countries, and their importance to e-participation may subside over time. This may occur with innovation capacity as well for developed countries. However, it may be the 2014-2020 time period was not long enough to capture changes in the citizens' perceptions because these aspects take longer to change.

The findings of this study reveal noteworthy evidence about the e-participation phenomenon and how stigmergic processes are involved. While local governments worldwide may be grappling with how to enable citizens to participate in local government through ICT use (Åström et al. 2012; Bawack et al. 2018), the results suggest multiple elements such as agent, sign, and environment work in concert to facilitate e-participation. In an era of globalization, pressures exist that contribute to the de-territorialization of local political authority (Bošnjak et al. 2008; Datta et al. 2005) and the aspirations of citizens to engage in decision-making which creates a good environment for e-participation.

The effectiveness of ICTs in e-participation is often associated with their use by citizens (agents) and the ability of authorities (agents) to channel demand for participation by providing new and more efficient/effective tools for interactive contact and communication, to involve citizens in the local policy-making process (Medaglia 2012; Sæbø et al. 2010; Zheng 2017). For example, the findings show a slight upward trend in citizen literacy across countries, but the slope is flat for

developed countries and may not be a significant agent factor in e-participation. However, between 2014 and 2020, the number of governments reporting substantial citizen social media and Internet engagement nearly doubled[9]. As a result, the mechanism of agent is a way for countries to understand e-participation success and address issues related to the transformation of the government-citizen (or agent-agent) relationship. This may help reverse trends over the last few decades, such as declining voter participation, crises in local decision-maker legitimacy, and resolve complex policy issues at the local level. E-participation emerges under various names, such as digital democracy, e-democracy, and e-voting. Each is a means to advance citizen engagement in participatory relationships with governments. Understanding how the factors within agent, sign, and environment operate will facilitate progress.

ICT Strategy for e-Participation

By 2030 (long-term goal), the UN Secretary-General has called for universal connectivity with affordable services, globally. With just nine years left, the planet faces a daunting challenge. Indeed, as the COVID-19 crisis has shown, we have even less time! Although we should be proud of how ICT has improved citizens' lives and helped them deal with the COVID-19 crisis, there is still a significant digital divide. According to the UN, 3.6 billion people are still without Internet access, and progress to improve connectivity is declining[10]. To develop a comprehensive ICT strategy that increases e-participation, we must first recognize that most ICT investments have

[9] www.un.org

[10] www.un.org

been made by the private sector, which accounts for more than 90% of all ICT investments.

Governments, on the other hand, must not overlook their vital position in developing ICT strategies to improve citizens' access to basic services, an important part of e-participation. For example, strategies could focus on smart and creative policies that build environments that encourage ICT investment. Several countries, including China, India, Brazil, and Japan, have increased government spending in the ICT sector over the last seven years, as their central governments encourage foreign investment[11].

The Asia Pacific and Middle Eastern regions are making strides in e-participation. Increased business activities, increasing investment flows, national infrastructure build-out, and government service expansions have increased the adoption and expansion of ICT services at rapid pace[12]. For example, the Indian government's initiatives, which aim to simplify digital platforms, are driving investments in the ICT sector. The government can now process automated and simplified data repositories thanks to the Digital India initiative. Another example is that the government of New Zealand has tasked the Chief Information Officer (CIO) with leading the ICT industry by allowing integrated digital service delivery, providing system-wide assurance, and achieving sustainable business savings of USD 100 million per year, since the year 2017. Table 7.1 below shows the top regional countries in ICT investment. Rather than allowing each government sector to spend

[11] https://www.oecd-ilibrary.org/sites/c5840db0-en/index.html?itemId=/content/component/c5840db0-en

[12] www.brookings.edu

its budget on ICT to enhance its own facilities and operations, it could be more effective and profitable for the government to implement a new whole-of-government ICT investment plan to coordinate all ICT investments and promote citizen access to services.

Table 7.1: ICT Investment in Government Regional Outlook (2014-2020)

Region	Countries
North America	USA, Canada, and Mexico
Europe	Germany, United Kingdoms, France, and Spain
Asia Pacific	China, India, Japan, and Australia
South America	Brazil
The Middle East and Africa	United Arab Emirates, and Israel

Figure 7.4 shows the growth trajectory of e-participation in both developed and developing countries. The EPI appears to accelerate similarly between 2018 and 2020 for both types of countries. Most governments and municipalities are pursuing digital government policies, many with novel initiatives, like the COVID-19 pandemic triggers lockdowns, but large numbers of citizens still lack access to online services, according to the United Nations[13] Survey recently released. Governments have put in place innovative technologies in response to the health emergency, such as special COVID-19 information sites, hackathons, e-services for medical products delivery, virtual medical appointments, self-diagnosis apps, and e-participation (Bolton et al. 2021). Apps for tracking and tracing, as well as apps for working and studying from home, were quickly used in several nations. Bhutan, Bangladesh, and Cambodia have advanced from the middle to the top of the category of least

[13] United Nations EGovernment Survey 2020

developed countries in terms of digital government development. Mauritius, Seychelles, and South Africa are at the top of Africa's government rankings.

Contributions

This research contributes to the e-participation research stream in several ways. In this section, I summarize the contributions to theory and practice to advance the e-participation literature. This study also makes contributions to the e-government and information systems literature and the stigmergy theory literature. I presented a novel theoretical framework, stigmergy theory, as a basis for evaluating e-participation. I developed research questions and evaluated them in a global context. I created a stigmergic model and developed hypotheses to test numerous factors in terms of their association with the EPI and their growth trajectories. All the data originated with publicly available archival datasets with repeated measures across specific time periods. I proposed LGM models and used the data from the United Nations to examine the e-participation factors' growth trajectories across countries and in relation to the EPI.

First, this work extends the research related to e-government from an information systems (IS) perspective to understand essential variables in e-participation. This work examined the IS body of knowledge about citizen participation in the electronic delivery of government services over the years. E-participation is critical to the success of e-government and this study also gives insight into the under-researched field that is too often in the shadow of the e-participation.

Using stigmergy theory, I adopt the point of view that there are three essential forms of research focus for e-participation research: Agent, Sign, Environment. These stigmergy mechanisms operate together, and future research could show how the factors within each element interact to produce e-participation. ICT resources are important for e-participation engagement by citizens, but other factors (e.g., literacy, laws) are also important to the growth trajectory of e-participation overall. Because ICT is becoming more affordable for governments and people, the government's spectrum of interaction with citizens will broaden, opening new possibilities and opportunities to explore ways for effective e-participation. My study suggests that non-ICT related factors should also be part of e-participation research because they affect how ICT is used by citizens and government authorities. A wide range of relevant agents, signs, and environment variables can be operationalized by researchers to understand e-participation, and then used to design or evaluate e-participation implementation in practice.

Second, I introduced a set of factors with data collected globally and publicly available for exploration. Although prior research has noted the importance of e-participation, there has been limited understanding of the essential factors and how they vary in the growth trajectory of e-participation. My study shows significant variation among the factors across the countries sampled as well as variation in the growth of the factors over time.

My study also answers the call to examine a new method in carrying out e-participation research (Medaglia 2012). Rather than perform predictive methods, my study shows the value of using longitudinal growth modeling to evaluate numerous,

inter-related, dynamic factors. The results of LGM analysis present insights into how the factors tend to contribute to the overall growth of e-participation. Such studies have the potential to identify the 'best' or 'most promising' e-participation growth factors to reduce the learning curve of developing countries in the beginning stages of implementing e-participation.

The study also makes practical contributions for the adoption of e-participation. When a country status is either developed or developing, significant differences in the growth trajectories of the factors appear. Some factors may contribute at a greater rate to developing countries e-participation, while others (e.g., literacy) may not contribute at all when a country has already achieved a higher level of a factor. Research at the country level would be most effective to understand how the factors vary, to develop better e-participation strategies.

Limitations

The dissertation research outcomes are best understood in the context of four main limitations. First, the data used for each factor and the EPI covered only 2014 to 2020. The United Nations Global Survey data was used to capture the EPI for each country. The data in 2020 may include more countries than used in my study, but these were eliminated from the analysis because LGM methods require at least three time periods of data. Second, stigmergy theory is limited in explaining the dynamics between agent, sign, and environment. Other theory might be useful to understand how the factors within agent, sign, and environment interact according to internal perturbations and external challenges. Third, different variations of the data could be fitted in LGM to give more insight into the factors and the EPI. I explored one

variation in dividing the data into two groups of countries based on their development status. Time and scope limitations prevented further analysis and provides opportunity for more research.

Finally, in this study, under the methodology of LGM the mean structure (i.e., shape of the overall changing pattern over time) and variance-covariance structure, which includes growth factor (i.e., variances across individual growth trajectories) and residual structure, was used to determine the model specifications in the LGM framework (i.e., variations within the individual growth trajectories). However, when searching for the accurate growth shape in simulations, previous research has consistently indicated that the saturated residual variance-covariance structure (i.e., freely estimating the variance and covariances of repeated measures) offered promising performance (Wu and West 2010); (Kim et al. 2016). Yet, existing recommendations are based on recent studies which assume that all latent growth factors are exogenous variables in population models. That is, no research has looked at whether current recommendations are still valid when growth latent factors are both exogenous and endogenous variables at the same time (Kim et al. 2018).

CHAPTER EIGHT

Conclusion

This study investigated the relationships between the e-participation factors, the EPI, and the growth trajectory of stigmergic mechanisms. Across all the countries, and in the context of the specific factors I examined for e-participation, all of the factors, except literacy, show a positive growth trajectory over 2014-2020. Adult literacy shows a flat growth trajectory. However, when a country has a high initial value for any of the factors, then the rate of growth declines over time. Internet use is the only factor that shows a non-significant growth rate when a country already has a high beginning rate of Internet use. Stigmergy theory provides the structure to group the factors into agent, sign, and environment as a way to understand their dynamism as they produce the e-participation outcome.

The ontology for the e-participation factors is a starting point for exploring the underlying framework for e-participation. The ontology will reflect the basic underlying principles for structuring the e-participation domain and developing the lines of inquiry for more advanced e-participation studies. Recent ICT ontology definitions can also allow the use of reasoning and inference mechanisms to advance e-participation research, and in a practical sense to find novel methods for knowledge management as well as tailored and customized ICT tools and services in a variety of e-participation contexts.

The findings of this study contribute to the theoretical discourse on e-participation by emphasizing the importance of ICT contextual factors in motivating citizen engagement. I discussed the importance of practical guidelines and ICT investment to 1) encourage government's willingness to improve government ICT investment, perceptions, and efficiency usage; 2) to leverage the effects of Internet and social media usage; and 3) to facilitate the willingness of governments to follow the e-participation blueprint of developed countries.

APPENDIX

APPENDIX

Supplementary Tables

Table A.1: Countries. Source: The United Nations.

Countries (147)
Albania, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivarian Republic of Venezuela, Bosnia and Herzegovina, Brazil, Brunei Darussalam, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Comoros, Costa Rica, Cuba, Czech Republic, Democratic People's Republic of Korea, Democratic Republic of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Finland, France, Georgia, Germany, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iraq, Ireland, Islamic Republic of Iran, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Latvia, Lebanon, Lesotho, Liberia, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Mexico, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Rwanda, Saint Lucia, Samoa, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, South Korea, South Sudan, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Thailand, Tunisia, Turkey, Tuvalu, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, VietNam, Yemen, Zimbabwe.

Table A.2: Developed Countries and Developing Countries.

Developed Countries (34)	Developing Countries (113)
Europe (26 countries): Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom The Americas (3 countries): Canada, Chile, United States Asia (3 countries): Israel, Japan, South Korea Oceania (2 countries): Australia, New Zealand	Arab States (16 countries or territories): Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Tunisia, United Arab Emirates, Yemen East Asia and the Pacific (17 countries): Brunei Darussalam, Cambodia, China, Indonesia, Democratic People's Republic of Korea, Malaysia, Marshall Islands, Mongolia, Palau, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Thailand, Tuvalu, VietNam Europe and Central Asia (12 countries): Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Montenegro, Serbia, Turkey, Ukraine, Uzbekistan Latin America and the Caribbean (26 countries): Argentina, Bahamas, Barbados, Belize, Brazil, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Uruguay, Bolivarian Republic of Venezuela South Asia (8 countries): Bangladesh, Bhutan, India, Islamic Republic of Iran, Maldives, Nepal, Pakistan, Sri Lanka Sub-Saharan Africa (34 countries): Angola, Benin, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, South Sudan, Uganda, Zimbabwe

Note: source, UN DESA, based on data of the United Nations Statistics Division and UN DESA forecasts.

Table A.3: List of Indicators in the World Telecommunication/ICT Indicators Database

Section	Sub-indicators Examples.
Economy demography	Percentage of the population in urban areas.
	Population.
Fixed Network	Basic-rate ISDN subscriptions.
	Faults per 100 fixed-telephone lines per year.
Mobile network	Mobile-cellular numbers ported.
	Mobile-cellular telephone subscriptions.
	Mobile-cellular telephone subscriptions per 100 inhabitants.
Traffic	Domestic fixed-to-fixed telephone traffic, in minutes.
	Domestic mobile-telephone traffic, in minutes.
Prices	Mobile broadband USB_1GB, prepaid, price of the plan.
Revenue/Investment	Annual foreign investment in telecommunications.
Employees	Full-time equivalent telecommunication employees, female.
	Full-time equivalent telecommunication employees, total.
	Persons employed by mobile-telecommunication operators.
Internet	Fixed Internet subscriptions.
	Fixed Internet subscriptions per 100 inhabitants.
Broadband	Active mobile-broadband subscriptions.
	Active mobile-broadband subscriptions per 100 inhabitants.
	Cable modem Internet subscriptions.
ICT Household	Percentage of households with computer.
	Percentage of households with Internet.
	Percentage of individuals using the Internet.
Broadcasting	Direct-to-home (DTH) satellite antenna subscriptions.
	Multichannel TV subscription.
Quality of service	Mobile-cellular unsuccessful call ratio (%).
	Mobile-cellular dropped call ratio (%).

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