A Process-Trace of Selected Innovation- and Technology-Led Economic Growth Factors and Their Implications for Estonia´s Economic Development

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Estonian Business School
Tallinn | Helsinki

Doctoral Thesis in Management
No. 36 Tallinn 2020

Estonian Business School

A PROCESS-TRACE OF SELECTED INNOVATION- AND TECHNOLOGY-LED ECONOMIC GROWTH FACTORS AND THEIR IMPLICATIONS FOR ESTONIA'S ECONOMIC DEVELOPMENT

Thesis for the Degree of Doctor of Philosophy

by

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Tallinn 2020

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Dissertation is accepted for the defence of the degree of Doctor of Philosophy in Management by the Research and Development Council of Estonian Business School on September 29, 2020.

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Public Defence on December 4, 2020 at Estonian Business School, Lauteri 3, Tallinn.

Language editor: Michael Haagensen

ISBN 978-9949-7418-8-5
ISBN 978-9949-7418-9-2 (pdf)

Estonian Business School, 3 Lauteri Street, Tallinn

DEDICATION

To **Michelle**, **Mikhail**, and **Kirk**

"Be inspired to attain higher laurels."

ACKNOWLEDGEMENTS

This work is the result of series of interactions with many people. First among them stands Professor Olav Aarna, who has accompanied me with uncountable pieces of advice and remarkable professionalism, continuous encouragement, guidance and support, greatly improving my ability to cope with my interactions. Professor Olav has been an outstanding supervisor, guiding by reminding me regularly the need to focus on the things that matter and for demanding independent action.

To the respondents during some of my studies, thank you for your time. I would like to appreciate the experiences made and the insights gained during my studies and bits of information I gathered through listening and observing closely, and from a distance, in my quest to understand the social context I was studying.

I would like to express gratitude for the various support and funding opportunities awarded to me to undertake this endeavour: The Research Council of EBS and Estonian Government via the appropriate ministries, Dora+ program and so forth.

Special thanks go to members of the Committee: Professors Põder, Kitsing and Elenurm for their input which improved this dissertation. Also, to Triin Sillaots and Maarja Laos.

Finally, I would like to express gratitude to my spouse, Akosua Sai, and entire family and friends for their enduring words of encouragement and support.

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III. **Sai, Andrew A.** (2018), An Exploratory Study of Innovation Adoption in Estonia, *Open Journal of Business and Management* [ISSN Print: 2329-3284, ISSN Online: 2329-3292, Vol. 6, No. 4]

IV. **Sai, Andrew A.,** Naroznaja, A. (2018) Analyzing the Vehicle Insurance Ecosystem in Estonia using Actor Network Theory (ANT), *European Scientific Journal*, ESJ, 14(26), 45, doi.org/10.19044/esj.2018.v14n26p45

V. **Sai, Andrew A.** (2018), Between Technological Change and Growth: A Review of Theoretical Concepts and Empirical Literature on Diffusion Models and Social Change, *11th RGS Doctoral Conference in Economics*, University of Duisburg-Essen, Germany

[1] Other research projects, considered not relevant to this work and not included here can be accessed via: https://www.researchgate.net/profile/Andrew_Sai2/research

LIST OF ABBREVIATIONS

ARDL	Autoregressive Distributed Lag
DFID	Department for International Development
DOI	Digital Opportunity Index
EENet	Estonian Educational and Research Network
EPO	European Patent Office
ERDF	European Regional Development Fund
EU	European Union
FDIs	Foreign Direct Investments
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GII	Global Innovation Index
GITR	Global Information Technology Report
GMM	Generalized Method of Moments
HDI	Human Development Index
HDR	Human Development Report
ICT	Information and Communication Technology
IMF	International Monetary Fund
ISIC	International Standard Industrial Classification
IT	Information Technology
ITU	International Telecommunications Union
LISA	Local Indicators of Spatial Association
LM	Lagrange Multiplier
MISP	Mini Information System Portal
NBER	National Bureau of Economic Research, USA
NRI	Networked Readiness Index
OC	Organizational Culture
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares

PA	Patent Applications
PPP	Purchasing Power Parity
RIS	Regional Innovation Strategy
RP	Research Problem
RQ	Research Questions
SII	Summary Innovation Index
SNA	System of National Accounts
SPOF	Single Point of Failure
SPSS	Statistical Package for Social Sciences
TFP	Total Factor Productivity
UN	United Nations
WEF	World Economic Forum

ABSTRACT

In recent times, the world has been facing a confluence of turbulent changes and technological advancements that are fundamentally altering the relationship between individuals, economies and societies. Innovations in diverse fields are individually disruptive and world changing. Nations that aspire to an innovation- and technology-led economy must first look to improve fundamental components of the economy, which are more dependent on the production, distribution and use of knowledge than ever before. Although scholars have different views on how to approach this, there is a shared understanding that existing assumptions and economic models need adjustment.

The innovation- and technology-led economy is understood in this work as an economy where the production, use and management of a country's resources by economic agents (individuals, businesses, organizations and governments) are associated with processes that involve predominantly, knowledge accumulation, technological innovation and human capital development. Innovation- and technology-led economic development is specified as improvements in the quality of life and living standards of a population in a country resulting from innovation- and technology-led economic growth.

It has been argued that Estonia's transition to a free-market economy and liberal democracy and digital transformation of its public sector not so long after its re-independence in 1991, are both linked to its success in terms of gross domestic product, exports and foreign direct investments. Some commentators and institutions have associated Estonia's digital success story to the data infrastructure architecture known as X-road combined with the

compulsory national identification card for this economic feat. Others suggest political consensus: privileging widespread cross-party support for a digital transformation from its inception. Estonia, by 2015, was among the top-performing internet-dependent countries in the world.

The economic literature suggests that innovation- and technology-led economic growth is driven by: (1) direct or economic growth determinants (e.g. research and development (R&D) expenditure, number of patent applications); (2) indirect or non-economic growth determinants (e.g. ICT infrastructure, innovation policy and technology governance). Therefore, determinants of economic development in such an innovation- and technology-led economy was selected as the **object of this dissertation**.

To differentiate, innovation- and technology-led economic growth factors are understood as the circumstances, facts or influences that contribute to economic growth and economic development. Meanwhile, innovation- and technology-led economic growth determinants have an evidenced causal impact on economic growth and economic development.

The **research aim** was to identify economic growth determinants and explore the implications for Estonia's economic development since 2000. The **research problem** (RP) was formulated as follows: What are the determinants of economic growth and economic development in Estonia between 2000 and 2015?

Explaining-outcome process-tracing was selected as the methodology to solve this problem. This makes an in-depth analysis of the selected case possible, while also providing direction towards the crafting of a minimally sufficient explanation of the mechanisms of sustained economic growth and high levels of productivity in Estonia over the study period – 2000 to 2015.

The RP was decomposed into four research questions (**RQs**):

- **RQ1**: How do direct and indirect factors influence economic growth and economic development?
- **RQ2**: What are the direct innovation- and technology-led economic growth determinants of Estonia's economic development since 2000?
- **RQ3**: What are the indirect innovation- and technology-led economic growth determinants of Estonia's economic development since 2000?
- **RQ4**: What recommendations concerning innovation governance and technology management in Estonia can be drawn from the process-tracing exercise?

To address **RQ1**, the relevant literature was analyzed to identify the factors of economic growth at the national level and how they influence economic growth and economic development. As a result, a **Conceptual Model of Innovation- and Technology-led Economic Development** has been developed connecting the main concepts of the study. In this model the selected direct factors of economic development (R&D expenditure, number of patent applications, human capital development, technological innovation, regional innovation capability) directly influence economic growth, while selected indirect factors of economic development (ICT infrastructure, innovation policy, technology governance) directly impact economic innovation, which in turn influences economic growth and economic development.

To address **RQ2** and **RQ3**, process-tracing tests were conducted to identify causal mechanisms. The impact of the selected economic growth factors on the economic development of Estonia was analyzed by (1) developing a causal sequence framework for the process through which the selected growth factors cause economic growth, depicted in the conceptual model (2) developing and specifying hypotheses to be tested about the likely causal relationship between selected economic growth factors and economic development; (3) identifying alternative choices and counterfactual outcomes; and (4) finding evidence for the primary hypotheses and also evidence for the rival hypotheses. Four tests were conducted based on the matrix for assessing the certainty and uniqueness of evidence, which prescribes the affirmation of sufficient or necessary causal inferences in process-tracing as follows: (1) straw-in-the-wind test; (2) hoop test (3) smoking gun test, and (4) Doubly decisive test. The inferences and conclusions drawn from the tests and evidence collected assert a degree of confidence in each part of the hypothesized mechanism.

The **research findings** from testing the hypotheses revealed that the distinction between direct and indirect growth factors is unambiguous and that a causal relationship may exist between selected economic growth factors, economic innovation, economic growth and economic development in Estonia. R&D expenditure and number of patent applications turned out to not be predictors of Estonia's economic growth, and therefore economic development. Meanwhile, human capital development and technological innovation are determinants of Estonia's economic development, having evidenced a causal impact on economic development. For the EU region, the results suggest that R&D expenditure but not the number of patent applications is a strong explanatory variable in regional economic development, confirming prior studies about unbalanced growth. In addition, the combined inferential weighting of evidence submitted in this work about economic growth factors lend further credence to the causal inferences, mechanisms and their interpretations for that matter. Further studies are required though, regarding the indirect factors if their contribution is to be established distinctively.

As a precursor to tackling RQ4, two pathways in Estonia's economic development were explored and their explanatory power harnessed to link causal mechanisms, the causal process and inferences generated from process-tracing.

Estonia's Digital Plan for Accelerated Economic Growth (referred to as the Digital Plan) was proposed as a result of process-tracing by sifting evidence, weighting it to uncover a plausible sufficient causal process through which the outcome of economic development was produced in Estonia. The Digital Plan, which outlines the strategic digital initiatives and programmes deployed to drive the Estonian digital transformation, explains the implicit strategy of economic development during the period studied. There are four phases in the digital phases of the Digital Plan: (1) Digital Foundation (2) Digital Inclusion (3) Digital Transformation and (4) Global Digital Leadership. To attain the Digital knowledge-driven Economy and Society Strategy of the Plan, four sub-strategies, considered foundational to developing a digital society, were rolled out:

(1) Digital hard infrastructure strategy
(2) Digital service infrastructure strategy
(3) Digital soft infrastructure strategy
(4) Digital knowledge-driven economy promotion strategy

To address **RQ4**, a number of practical recommendations are made towards shifting the focus of an economy from industry-based to one that is innovation- and technology-led. These recommendations are the lessons drawn from the research process and outcome, and include: developing and upgrading the economy through the use of ICTs; enhancing the competitiveness of the ICT industry and providing enablers to support innovation and an entrepreneurial mindset; developing human capacity by increasing the application of ICT in education and training; investing in the national ICT infrastructure; and investing in good governance by providing the use of ICT across all government agencies.

In terms of a **theoretical contribution**, this study presents an example of how to contextualize and operationalize the process-tracing methodology in business and management studies. The conceptual model proposed provides a framework for identifying innovation governance and technology management concepts and reflecting the complex relationships between them. The model can be used in similar future studies.

The contributions of this work when **applied** provide a unique case of how to conceptualize in translating a causal theory into a theorized mechanism that can explain how one variable causes another. In addition, when applied, this work provides an example of how to test whether theorized mechanisms can be observed in empirical materials in relation to innovation in economic analyses. It provides a trace of growth factors and their potential causality link to economic growth and sustained economic development. This is significant for country-level policy and strategy towards an innovation- and technology-led economy and meeting the digital economy benchmarks following Estonia's Digital Plan for Accelerated Economic Growth. It is important to note that while the research findings resulting from the explaining-outcome process-tracing are not generalizable, especially for single within-case analysis results, the Digital Plan and recommendations can be extrapolated for use in other similar countries. However, caution should be exercised in such generalizability, since the causal process, causal mechanisms and causal inferences for other cases may be entirely different.

A major **limitation** of this research is in operationalizing process-tracing within a single case. The concept has not been fully developed and there are no clear-cut guidelines for its contextualization and operationalization, and therefore the introduction of researcher-bias in the inferences proffered is possible. The four tests are also not clearly developed in the sense that what constitutes a "smoking gun" test result, may not necessarily be the outcome offering the best possible explanation of a potential causal relationship, as was seen with the Hoop test and straw-in-the-wind test outcome.

Keywords: Estonia, Economic Innovation, Economic Growth Determinants, Innovation- and Technology-led Economy, Innovation Policy, Process-tracing, Regional Innovation Capability, Technology Governance

1. INTRODUCTION

In recent times, the world has been facing a confluence of turbulent changes and technological advancements that are fundamentally altering the relationship between individuals, economies and societies. Innovations in a diverse set of fields including robotics, genetics, artificial intelligence, internet-enabled sensors, and cloud computing are individually disruptive. Collectively, in the views of Rice and Yayboke (2017), they are world changing. Nations that aspire to an innovation- and technology-led economy must first look to improve fundamental components of the economy, which in contemporary times are more strongly dependent on the production, distribution and use of knowledge than ever before. Although scholars have different views on how to approach this, there is a shared understanding that existing assumptions and economic models need adjustment. The literature suggests that there are clear opportunities to accelerate and expand the opportunity for innovation and technology around the world. For developed and developing nations, the innovation- and technology-led economy offers significant risks and opportunities.

Innovation economics scholars, particularly Schumpeter (1934), Solow (1956) and more recently Romer (1980) have: (1) argued that economic growth results from exogenous factors in the economic system while economic development is caused by economic innovation; (2) asserted that a connection, of a long-term nature, exists between economic growth and innovation; and (3) incorporated technological change and innovations into economic growth models. Before these new growth contributions were projected, the traditional model of development relied on agriculture, commodities, and cheap labor as part of an incremental process to build skills, move up global chains and increase national incomes. In this new paradigm, nations that want to thrive in the transforming global economy must change their economic trajectory and industrial mix through innovation and technology.

The economic literature suggests that innovation- and technology-led economic growth is driven by: (1) economic or direct growth determinants (e.g. research and development (R&D) expenditure, number of patent applications); (2) indirect or non-economic growth determinants (e.g. ICT infrastructure, innovation policy and technology governance). **Therefore, determinants of economic development in an innovation- and technology-led economy was selected as the object of this dissertation.**

Kattel et al. (2018) have argued that Estonia's transition to a free-market economy and liberal democracy and digital transformation of its public sector not so long after its re-independence in 1991, are both linked to its success in terms of gross domestic product, exports and foreign direct investments. Estonia has been touted as "The Baltic Tiger." Several global indicators and metrics have placed Estonia positively and in good stead in terms of country growth and development leveraged on information and communication technologies (ICTs). For example, the EU Digital Economy and Society Index (DESI) in 2017 had Estonia leading in digital public services, while ranking 16th globally on the United Nations (UN) 2018 e-government survey, not to mention the Networked Readiness Index (NRI), on which Estonia ranked between 18th and 26th between 2000 and 2015. The New Yorker in 2017 summarized Estonia's creation of a digital state with digital citizens, which was published as "Estonia, the digital republic", and subtitled: "Its government is virtual, borderless, block-chained and secure. Has this tiny post-Soviet nation found the way of the future?" Estonia, in contemporary times is among the top performing internet-dependent countries in the world.

Recent records show that the structure of the Estonian economy has changed significantly. Estonia's economic records showed that GDP per capita was 15,186 euros in 2014, about 759 Euros more than the previous year 2013, compared to the about 4,070.03 US dollars in 2000. Of significance is the fact that by 2014, more than 68% of the gross value added in Estonia was created in the service sector, as reported by the national statistics office of Estonia, Statistics Estonia. According to the same office, for example, in 2014 the expenditure on research and development (R&D) in Estonia amounted to 286.7 million euros, while retail trade enterprises increased by 8 percentage points at constant prices between 2014 and October 2015. The retail sales of goods stood at 442.7 million euros at the end of 2015. As another example, by October 2015, the production of industrial enterprises decreased by 2 percentage points in the areas of manufacturing, energy and mining in Estonia (Statistics Estonia database, 2015). These are significant signals about the transformation in economic growth model towards an innovation- and technology-led growth model, where consumption, services and higher value-added manufacturing and innovation are the major sources of economic growth, where tangibles such as the traditional factors of production are replaced with new independent forces such as human capital, innovation and technology. **Therefore, Estonia as an innovation- and technology-led country was chosen as a case to study more closely in this dissertation.**

To establish whether selected economic growth factors drive economic growth in an innovation- and technology-led economy, the **causal puzzle** of this dissertation was stated: that growth determinants in innovation- and technology-led economies stimulate economic innovation, and impacts the economic growth and development of nations. Estonia's economic transformation and success served as the motivation for selecting Estonia as the case study for this work. In addition, its relatively small population makes it a good case for this exploratory work. While there is no question about what the sources and types of growth are in economics literature, this **dissertation aims** to **process-trace economic growth determinants and explore the implications for Estonia's economic development since 2000**. In this regard, the **Research Problem** was formulated as a root research question: **What are the determinants of economic growth and economic development in Estonia between 2000 and 2015?**

Explaining-outcome process-tracing was selected as the methodology to answer this question. This will allow an in-depth analysis of the selected case, while also providing direction towards the crafting of a minimally sufficient explanation about the mechanisms of sustained economic growth and high levels of productivity in Estonia between 2000 and 2015.

The Research Problem was decomposed into four **Research Questions (RQs)**:

- **RQ1**: How do direct and indirect factors influence economic growth and economic development?
- **RQ2**: What are the direct innovation- and technology-led economic growth determinants of Estonia's economic development since 2000?
- **RQ3**: What are the indirect innovation- and technology-led economic growth determinants of Estonia's economic development since 2000?
- **RQ4**: What recommendations concerning innovation governance and technology management in Estonia can be drawn from the process-tracing exercise?

To address **RQ1**, relevant literature is analyzed to identify the national factors of economic growth and how they influence economic growth and economic development. As a result, a **Conceptual Model of Innovation- and Technology-led Economic Development** (Conceptual Model) will be developed connecting the main concepts and variables of the study and serving as a framework to solve the causal puzzle. In this model, the relationship between the direct factors of economic development (R&D expenditure, number of patent applications, human capital development, technological innovation and regional innovation capability), indirect factors of economic development (ICT infrastructure, innovation policy, technology governance), economic innovation, economic growth, and economic development is analyzed.

To address **RQ2** and **RQ3**, process-tracing tests are conducted to establish the causal mechanisms. The respective research design consists of the following steps:

1. Developing the causal sequence of the process through which the selected growth factors cause economic growth;
2. Developing and specifying hypotheses to be tested;
3. Identifying alternative choices and events in the causal sequence;
4. Identifying counterfactual outcomes;
5. Finding evidence for the primary hypotheses and also evidence for the rival hypotheses.

By combining the description of the events, causal pathways and mechanisms, process-tracing converts historical narratives into causal explanations, which makes for a robust explanation about the outcome of economic growth in Estonia. Four tests are conducted based on a **Matrix for assessing the certainty and**

uniqueness of evidence as prescribed by Beach and Pedersen (2013):

1. Straw-in-the-wind test.
2. Hoop test.
3. Smoking gun test.
4. Doubly decisive test.

The Matrix is used as a Method of Elimination and Decision Criteria in this work. Though subjective, the inferences and conclusions assert a degree of confidence in each part of the hypothesized mechanism, based on the evidence collected and tests applied.

To address **RQ4**, exogenous and endogenous pathways of Estonia's economic development are analyzed, which will lead to policy recommendations concerning the development of the digital knowledge-driven economy.
It is necessary to clarify the following key constructs and concepts as applied and implied in this dissertation to avoid any terminological misunderstanding, given that there are many associations of these concepts in the vast field of innovation economics literature.

The term **innovation- and technology-led economic growth factor** in this dissertation refers to a circumstance, fact or influence that contributes to the outcome of economic growth and economic development. An **innovation- and technology-led economic growth determinant** is a factor that has evidenced a causal impact on economic growth and development.

An **innovation- and technology-led economy** is an economy where the production, use and management of a country's resources by economic agents (individuals, businesses, organizations and governments) are associated with processes that involve predominantly knowledge accumulation, technological innovation and human capital development. The innovation- and technology-led economy is a knowledge-based economy (see section 2.3).

Innovation- and technology-led developments are technological, spatial, economic, occupational, and cultural improvements in the quality of life and living standards of a population in a country, resulting from innovation- and technology-led economic growth.

Economic innovation in this dissertation is a process which reformulates the economic growth model of a country so that intangible innovation- and technology-led economic growth factors such as knowledge accumulation, technological innovation and human capital development are positioned as forces at the center of the innovation- and technology-led economic growth model.

Other basic concepts are defined and appended to this work (see Glossary)

The **author's publications,** which are inextricably linked to this dissertation, contain contributions from studies directly associated with the innovation and technology theories, concepts and frameworks covered or discussed in this work – some of which should have been elaborated far more exhaustively in this dissertation, if it were not for space constraints. In addition, the publications all focus on Estonia's growth, economic and technological developments.

This dissertation consists of seven chapters, including the Introduction and Conclusion, and the Appendices. The Introduction sets the scene for the study, explaining the motivation and basic elements of the research design. Chapter 2 presents the theoretical background of the study, introducing the key concepts and the factors of economic growth, and developing the hypothesized mechanisms. Consequently, the Conceptual Model is proposed. Chapter 3 covers different aspects of the research design developed to integrate the parts of the study into a coherent and logical package to address the Research Problem.

Chapter 4 analyzes the causal relationship between the selected direct economic growth factors and the economic growth of Estonia. Chapter 5 analyzes the causal relationship between the selected indirect growth factors and the economic growth of Estonia. Chapter 6 presents an assessment of the inferential weight of evidence submitted in the dissertation. The chapter closes with an analysis of the causal mechanisms, causal sequence framework and process. Practical recommendations developed from the results of process-tracing Estonia's economic development are also outlined. Chapter 7 summarizes the key findings and limitations of the study and their implications, proposes future research avenues by identifying challenges and opportunities during the research.

The Appendices include subsidiary materials, such as tables serving as supplementary explanations, statistics and bibliographic material appended to the dissertation.

2. THEORETICAL BACKGROUND

This chapter analyzes key concepts related to economic growth factors in innovation- and technology-led economies. Key constructs are already defined in Chapter 1. This chapter focuses firstly on the evolution of economic growth and economic development models in section 2.1. This is followed by an analysis of economic growth factor classifications describing economic growth factor groupings based on common characteristics into direct and indirect factors in the section 2.2. Section 2.3 develops an innovation- and technology-led economic development framework, which clarifies important notions and concepts in the dissertation. In sections 2.4 to 2.7, a selection of innovation- and technology-led economic growth factors are analyzed. At the end of such an analysis, a conceptual model of innovation- and technology-led economic developments, which describes the relationships between the processes involved in the economic development of a country is designed and developed. The analyses seek to answer RQ1.

RQ1: How do direct and indirect factors influence economic growth and economic development?

2.1. Evolution of economic growth and development models

Economic literature has been preoccupied with the issue of economic growth. Generally, economic growth has been understood to establish the conditions for economic development. Economic growth models highlight the different ways and processes in which economic growth factors can have an influence on economic developments, depending on the period and the dynamics of the economy studied. Models of economic growth such as the Lewis, Rostow, Harrod-Domar, Solow and Romer growth models, among others have made seminal contributions to this vast field of literature. Central to economic growth models are economic growth factors and economic growth determinants. An **economic growth factor** is understood in this dissertation to be **a circumstance, fact or influence that contributes to the outcome of economic growth and economic development**. An **economic growth determinant** is understood in this work **to be a factor that has evidenced a causal impact on economic growth and economic development**.

Is there a distinction between economic growth and economic development? Historically, economic development has been considered in different ways. Hirschman (1958) summarized the view of some early economic development theorists, but was mindful that:

> ...in general, economic development means transformation rather than creation *ex novo*: it brings disruption of traditional ways of living, of producing, of doing things, in the course of which there have always been many losses; old skills become obsolete, old trades are ruined, city slums mushroom, crime and suicide multiply, etc., and to these social costs many others must be added, from air pollution to unemployment.

Brinkman (1995) said, in noting the distinction between economic development and economic growth:

> A frequent distinction was made in which growth referred to a quantitative increase in GNP/capita and development entailed something more. Usually, development was conceptualized as qualitative changes in institutions and structure, relevant to the "non-economic" variables emphasized.

The most important distinction between economic growth and economic development has been in terms of measurability. Economic development has been broadly considered in the literature to refer to improvements in the quality of life and living standards of a population in a country resulting from economic growth. Due to the broad nature of economic development, debates have been ongoing about what the distinction is between economic growth and economic development. Supamoko (2016) asserted that in measuring economic development, one of the indicators that can be used is the measure of economic growth, in terms of gross domestic product (GDP) growth. Ramayani (2012) and Sukirno (2015) have emphasized that economic development results from economic growth. Their arguments have been that high economic growth is capable of encouraging a faster economic development process. However, Henry (1987), King and Levine (1994), and Levine (1998) also argue that there could be economic growth without economic development. The level and rate of economic growth does not always reflect the real level of a population's living standards. Brinkman (1995) argued that:

> To clarify a conceptual distinction between economic growth and development, three basic questions should be addressed: (1) What is the substantive nature of the process? (2) What is the structure and form of the process of development? And (3) How can the growth and development process be explained?

Brinkman (1995) suggested that, it is this distinction between economic growth and economic development that Kuznets (1966;462) had characterized as the "thorough transformation of a country's economic and social framework".

Economic growth[2], on the other hand, is not a new phenomenon. Economic growth as a concept has been considered in many ways by economists. For example, Kuznets (1934) defined economic growth as an estimation of the value added in a country, including the total value of all goods and services and which also represents growth in national income and in the wealth of nations. Denison (1962) affirmed this and added that an increase in real GDP per capita is economic growth. Kuznets (1973; 247) again offered a more comprehensive definition of economic growth, this time with a focus on technology and innovation:

> A country's economic growth may be defined as a long-term rise in capacity to supply increasingly diverse economic goods to its population, this growing capacity based on advancing technology and the institutional adjustments that it demands. All three components of the definition are important. The sustained rise in the supply of goods is the result of economic growth, by which it is identified. [...] Advancing technology is the permissive source of economic growth, but it is only a potential, a necessary condition, in itself not sufficient. If technology is to be employed efficiently and widely, and indeed, if its own progress is to be stimulated by such use, institutional and ideological adjustments must be made to affect the proper use of innovations generated by the advancing stock of human knowledge.

Romer (1990) saw economic growth in a more metaphorical fashion, as:

> Economic growth occurs whenever people take resources and rearrange them in ways that are more valuable. A useful metaphor for production in an economy comes from the kitchen. To create valuable final products, we mix inexpensive ingredients together according to a recipe. The cooking one can do is limited by the

[2] Economic growth is considered differently by economists. The definitions specified are examples and not representative of the entirety of definitions in the literature.

> supply of ingredients, and most cooking in the economy produces undesirable side effects. If economic growth could be achieved only by doing more and more of the same kind of cooking, we would eventually run out of raw materials and suffer from unacceptable levels of pollution and nuisance. Human history teaches us, however, that economic growth springs from the better recipes, not just from more cooking. New recipes produce fewer unpleasant effects and generate more economic value per unit of raw material.

The definitions of economic growth are inexhaustive. Some international organizations such as the OECD have concluded that "economic growth is neither a mechanical nor smooth process." This is re-emphasized by organizations such as the Department for International Development (DFID). The inclusion of "continuous improvement" affirms this assertion. In the DFID United Kingdom report (2011), economic growth was defined as:

> …the continuous improvement in the capacity to satisfy the demand for goods and services, resulting from increased production scale and improved productivity (innovations in products and processes)…

Now, economic growth models depict the different patterns of economic growth in different countries at specific points in time. The process of economic growth and development is seen to be based on a great variety of circumstances that change over time. For example, the United Kingdom was the leading industrialized country in the nineteenth century, followed by Germany and France. The United States then leapfrogged the European countries at the close of the nineteenth century according to Semmler, Greiner and Gong (2005):

> This marked difference in economic performance [of countries] is not accidental, for in some countries major forces of growth were set in motion that were lacking in other countries.

Economists started to conceptualize the process of economic growth in models since the days of Smith (1773). Models of economic growth (sometimes used interchangeably with theories[3] of economic growth) are considered representations of economic growth theories applied or their empirical representations. Models of economic growth necessarily apply some implications, which consist in classifications and the aggregation of factors of economic growth. Models of economic growth describe the cause-effect relationship between factors of economic growth, and economic growth and economic development, which lay the foundation for any comprehensive study of the economic development of countries. Economists assumed there should be a cause-effect relationship between some factors influencing economic growth (as inputs in the process) and the economic growth and economic development of countries (as outputs in the process) in their economic growth models.

Solow (1994) associated economic growth models with three theoretical waves: the Harrod-Domar contributions as the **first wave**; the development of the neoclassical theories as the **second wave**; and the **third wave**, which began in response to omissions and deficiencies in the neoclassical theories.

Economic growth models have been depicted in many ways. They are usually classified by extracting a common underlying

[3] Theories of economic growth and development explain the cause-effect relationship described by models of economic growth and development. Solow (2009) put it simply: “All theory depends on assumptions which are not quite true. That is what makes it theory. The art of successful theorizing is to make the inevitable simplifying assumptions in such a way that the final results are not very sensitive. A ‘crucial’ assumption is one on which the conclusions do depend sensitively, and it is important that crucial assumptions be reasonably realistic.”

assumption. For example, savings rate was considered exogenous[4] in the models by Harrod (1936) and Domar (1946), Solow (1965) and Uzawa (1963), which used the production function[5] "*AK*". For other models, savings rate was considered endogenous,[6] such as the models of Ramsey (1928) and Kaldor (1956). In most models of economic growth, a depreciation rate for capital and growth of the population are considered exogenous. The consideration of economic growth factors as exogenous and endogenous relate to underlying assumptions by theorists typically in terms of how economic growth factors are represented mathematically in their models. For example, in calculating the total output (real GDP) of a given economy (Y), the production function (F) is given by $Y=AF(K,L)$, where Y could be explained by capital (K), labor (L) and knowledge accumulation (A); A was considered a factor external to the economic growth models until the mid-1980s. Models of economic growth have also been divided according to the capital ratio contribution. As an example, the Harrod (1939) and Domar (1946) models assumed a constant value. Meanwhile, for neoclassical models, the ratio of capital/production changes over time. Models of economic growth have also been divided according to the criterion of time. For example, in Wozniak's (2008) analysis of models of economic growth, he noted that long-term models have been used primarily to determine the path of sustainable growth and characterize a pattern according to which the economy should grow.

[4] Exogenous growth theory is associated with neoclassical growth theory and holds that the long-run rate of economic growth is exogenously determined by either the savings rate (Harrod-Domar model) or the rate of technical progress (Solow model). However, the savings rate and rate of technological progress remain unexplained. See Acemoglu (2009)'s elaboration in his work, "*The Solow Growth Model*" in the book "*Introduction to Modern Economic Growth*".

[5] Production functions, generally in economics, relate the physical output of a production process to the physical inputs or production factors. This is expressed as a mathematical function that relates the maximum amount of output to be obtained from a given number of inputs, generally capital and labour.

[6] Endogenous growth theory holds that economic growth is primarily the result of endogenous and not external forces, so that investment in human capital, innovation and knowledge are significant contributors to economic growth. See Romer (1994), "*The Origins of Endogenous Growth*" published in the Journal of Economic Perspectives.

Meanwhile, short-term models have been used to identify the potential for having the level of actual production approach the level of potential output.

Before Solow (1994) considered the first wave, classical economists[7] saw factors fostering economic growth in *investments*[8] and in *improving the productive capacity* of a country. These classical economists argued that the development of market forces and economic growth would likely be accompanied by inequality, and that as economies expanded, traditional sectors and traditional methods of production would be rendered obsolete, the workforce would be deskilled, and the income of some groups depressed such that economic agents (individuals, businesses and governments as economic actors) took advantage of such opportunities to create wealth and accumulate fortunes. One of the classical economists, Smith (1776) postulated that increasing the size of markets as well as increasing returns and externalities due to a rising division of labour, would spur economic development. Smith (1723) had proposed the *division of labour* as a factor of economic growth and argued that the division of labour is a result of capital accumulation and gradual expansion of markets. He appreciated the role of technological innovation in the process of economic growth but not as an independent economic growth force. There were disagreements about which factors determine economic growth, but in general the classical economists recognized the divergence in income between sectors and groups. According to Semmler (2005:2), this was "conceived as a growth process that converges in the long run towards a stationary state of per capita income".

[7] Groenewegen (1969) analysed the position of the classical economists, which was published in the "Labour History" journal. Kim (2009) provides a full narrative of Adam Smith's contribution to economic growth history in "Adam Smith's theory of economic history and economic development".
[8] Italicized words are economic growth factors identified in the literature as wielding causal impact on economic growth at specific points in time.

Contrary to what the classical economists suggested in their models, Schumpeter (1934) did not consider the accumulation of capital as the main factor driving economic growth. He advocated the "instability of capitalism" in 1928, due to the disequilibrium effect of technological change on the irregular series of shocks in the economy. He attached great importance to the concept of entrepreneur-innovator and provided the setting for the development of research into the contribution of technological change to economic growth. In his contribution, which was extended by Usher (1954), Ruttan (1959) and Kuznets (1965;357), Schumpeter (1934) said the innovation and creativity of entrepreneurs were major factors determining economic growth. To Schumpeter, the entrepreneur introduces an innovation and receives great profits for it, but over time, the market competition copies the invention and profits begin to decline. His works assumed that private property, a competitive market, the efficiency of the financial market could support the production of new inventions. Schumpeter observed:

> Innovation is at the center of economic growth causing gales of creative destruction. [...] Innovation is a process of industrial mutation, that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.

The problem with Schumpeter's work was that the conditions he postulated existed only in democratic and economically developed countries.

2.1.1. First wave economic growth models

In the first theoretical wave, Harrod (1939) and Domar (1946) independently developed similar models (which were then combined) that sought the possibility for sustainable growth by extending the Keynesian model[9] that assumes the instability of the capitalist economy. In the Harrod (1939) and Domar (1946) models, economic growth is sustainable if three growth rates are equal: the actual growth rate, guaranteed growth rate and natural growth rate. To them, the achievement of this macroeconomic balance ensures full use of capital and labour. The Harrod (1939) and Domar (1946) models revealed two problems: First, the growth of a capitalist economy at the guaranteed rate of growth with full employment is not possible and that the process of economic growth is always accompanied by involuntary unemployment. Second, in a capitalist economy, there is no convergence towards equilibrium. Therefore, these models, by seeking a dynamic equilibrium path, proved the unsustainable character of economic growth. The Harrod-Domar (combined) growth model required a radical overhaul if it was to offer the dynamics of growth over time. The model needed some flexibility to accommodate technological change. Therefore, the substitutability of labour and capital was introduced to the model.

2.1.2. Second wave economic growth models

During the second theoretical wave, neoclassical economists identified three factors of economic growth: *land*, *labour* and *capital*, in the first half of the twentieth century. At the time, these factors were enough to explain the causes of growth in capitalist countries. It seemed then that the more these factors were utilized, the greater the economic growth levels, suggesting they had evidenced causal impact on economic growth processes. The neoclassical economists focused on capital accumulation. To them, increasing factors of economic growth such as capital and labour led to diminishing returns, and that rather by increasing the proportion of GDP

[9] The New School of Economic Theorists were pro-Keynes - John Maynard Keynes (1936) - and called the “rational expectations revolution.” See Lissner (1985) for a fuller account of Keynesian theories.

invested and technological progress, the productivity of capital and labour increased. Later, Solow (1957) demonstrated the insignificant share of land, capital, and labour in the economic growth of the United States and pointed to *technological progress* as having evidenced causal impact on growth in the US economy. In the words of Keita (2018):

> The neoclassical growth model as proposed by Solow (1956) [and Swan (1956)] proved itself to match economic reality. The growth and technological changes of Japan, South Korea and Taiwan were deemed to derive from technological changes. It is in this regard that the Solow model is identified with neoclassical growth theory. Thus, despite the plethora of growth theories that followed Keynes' macroeconomic prescriptions as to how to set the conditions for economic growth, the dominant growth theory was that of Solow's (1956) – specifically the Solow-Swan model – fully within the neoclassical paradigm. It is this specific model that has been promoted over the years by institutions such as the IMF and the World Bank.

The economic growth models developed by neoclassical economists during the second theoretical wave began with Solow (1956) and Swan (1956). They both proposed a long-term economic growth model in response to the unsatisfactory results derived from the models of Harrod (1939) and Domar (1946). Solow (1956) and Swan (1956), whose models were similar, aimed to show that in the long run, an economy achieved sustainable growth, at which point the growth rate of income per capita was equal to the rate of population growth. They introduced the assumption of the substitution of factors of production, which in turn removed the assumption of a constant ratio of capital/production. The contributions of Solow and Swan resolved the two problems identified in the Harrod (1939) and Domar (1946) models – the instability of the economy and the impossibility of the full use of labour.

Lewis's (1954) model of economic growth and development was interesting because of the fact that it was founded on the notion that in a society with an excess of rural-based subsistence wage labour, and an urban-based capitalist class, both sectors of the economy could interact in such a way that the cheap labour migrating from the rural areas could serve as a catalyst for growth and development. He accepted the classical Keynesian argument that for an economy to grow there must be adequate savings to invest to make growth possible. However, Lewis (1954) argued that this would not be feasible for developing nations because savings rates were very low in general and because the wealthy in those societies tend to be landowners who would either consume their rental surpluses or spend on non-productive items and enterprises. Based on Lewis's work, Kuznets (1955) developed a theoretical support called the "Kuznets curve". He argued that empirical studies had confirmed the existence of economic disparities in the early stages of growth and that initially, when labour began to abandon agriculture for industry, the differences were greatest; however, when the concentration of factors of production took place in industrial centres, the differences disappeared, suggesting a positive association between the dynamics of economic growth and the increasing share of urban population in the total population.

In Rostow's (1960) model, he argued that economic growth is dependent on the accumulation of capital by distinguishing five stages of economic development. To him, the biggest problem for poor countries is to achieve the third stage of the Rostow model, which he called "take off" because poor countries have problems with the interruption of the "vicious cycle" established over the years.

Japanese economist, Uzawa (1963) presented a model of economic growth composed of two sectors – the first sector produces consumer goods and the other, capital goods. In this model, when the ratio of capital/labour in the branch producing consumer goods was higher than in the branches producing capital goods, the model was stable.

Ramsey (1928) developed a model concerning the problem of the optimal level of savings. This was later extended by Cass (1965) and Koopmans (1965). In the Ramsey model, the savings rate is a factor endogenous to the model and depends on the decisions of consumers. Diamond (1965) introduced an economic growth model around the same period as Ramsey's, which he called "analysis of the finite horizons". In this model, the life of households is divided into two periods: households receive wages in the first period, which they spend on current consumption and savings. In the second period, households do not earn. The current consumption is financed by accumulated savings from the first period, which results in long run stable state.

Generally, the neoclassical models assumed that the economy achieved equilibrium in the long run. They also confirm the existence of convergence (i.e. faster development of poor countries in comparison with rich ones). The convergence hypothesis, which was extended later by scholars, such as Sala-i-Martin (1996), Barro (1991), Mankiw, Romer and Weil (1992), states that countries differ from each other only in their capital/labour ratio and that they have the same steady state. Hence the economy with a lower level of income per capita will obtain a higher rate of economic growth.

The challenge with the neoclassical models was that when confronted with data, the central tenet could explain only a fraction of the variations in growth rates, while the rest was attributed to technological progress (Solow, 1957; Maddison, 1987). In general, the neoclassicals left technological progress unexplained in their models. Arrow (1962) questioned the results derived from neoclassical models. According to him, conditioning the economic growth factors exogenous to the neoclassical models is not very satisfying. To Arrow, the obtained knowledge is the result of a process he called "learning by doing" (which Sala-i-Martin (2000) later called "learning by investments"). The problem with the Arrow model was that the model did not make long-term growth dependent on the level of savings. Just like the Solow (1956) and Swan (1956) models, in Arrow's model, economic growth in a steady state is determined by factors which are exogenous to the Arrow model. Arrow, however, shared the views of Schultz (1961) on the importance of human capital in the process of economic growth. Schultz argued that the costs for education, health and professional development are an investment in human capital.

2.1.3. Third wave economic growth models

In the third theoretical wave[10], the seminal contributions of Romer (1986), a Nobel Prize Winner, are noteworthy. Other scholars in the stream include Lucas (1988), Aghion and Howitt (1992), Sala-i-Martin (2001) and Barro (2004). According to Caroll (2019):

> Romer (1986) relaunched the growth literature with a paper that presented a model of increasing returns in which there was a stable positive equilibrium growth rate that resulted from endogenous accumulation of knowledge.

[10] In the third wave, an alternative to the factors suggested by the neoclassicals was their replacement with factors such as knowledge, innovation, and human capital. Endogenous growth theories emerged as part of the third wave. Endogenous growth theory holds that economic growth is primarily the result of endogenous and not external forces and that investment in human capital, innovation, and knowledge are significant contributors to economic growth (Romer, 1990). Scholars in this stream include e.g. Aghion & Howitt (1998, 2009); Barro & Sala-i-Martin (2003); Acemoglu (2009); Galor (2011); Weil (2012); Jones & Vollrath (2013).

Romer (1986) set the stage for endogenous growth models when he introduced capital externalities into the neoclassical growth models, endogenizing technological change in the mid-1980s. He extended the work of the neoclassical economists, particularly the works of Solow (1956). The neoclassical models were characterized by increasing returns to scale for all factors of production and the constant returns to scale for capital, which laid the very foundation for the existence of endogenous growth. However, in Romer's model, the growth of the economy requires the fulfilment of certain conditions: size of externalities must be significant, otherwise the economy grows according to a Cobb-Douglas function.[11] All the same, Romer's model foresaw the existence of "scale effect". Lucas (1988) defined the value of the scale effect as capital per capita, so as not to make assumptions about the zero increase of labour.

In Lucas's (1988) model of endogenous growth, there are two sectors and two types of capital – physical capital used in the production process and human capital that affects the growth in productivity of both labour and physical capital. Therefore, a certain person with human capital h produces two times more goods than a person with human capital $h/2$ and two times less than a person with human capital $2h$. Lucas acknowledged the existence of increasing returns to scale, and like Romer, referred to Arrow's concept of learning by doing. It must be noted that in the case of Romer's model, the source of externalities was the accumulation of physical capital, while in Lucas' model, the existence of externalities was based on the accumulation of human capital (Barro, Sala-i-Martin, 2004). Lucas' model explains the differences in economic development between countries. Countries characterized by a low level of human

[11] In economics and econometrics, Cobb-Douglas production function is a particular function form of the production function widely used to represent the technological relationship between the amounts of two or more inputs and the amount of output that can be produced by those inputs. See Labini (1995), Battese (1997).

capital grew more than countries with considerable resources in this respect.

In other endogenous growth models, economic growth is achieved via the endogenization of technological progress, which is the result of a functioning research and development (R&D) sector. Endogenous technological progress can manifest itself in two ways: expressed by increasing the number of goods and services used in the production process or reflected by improving the quality of existing goods and services. Aghion and Howitt (1992) also developed an economic growth model. In their model, technological progress is reflected in improvements in the quality of existing goods on the market. In contrast to Romer's model, the appearance of improved goods and services automatically replaces the old. They also argued that a country with more resources of educated people will grow faster than a country with a lower level of human capital.

To summarize, from a historical point of view, existing economic growth models have attempted to describe the cause-effect relationship between some factors influencing the economy (as inputs in the process) and economic growth and economic development (as outputs in the process) as described by the various models seen in the various theoretical waves. **This study will focus on the third wave**. The third wave is associated with endogenous growth models.

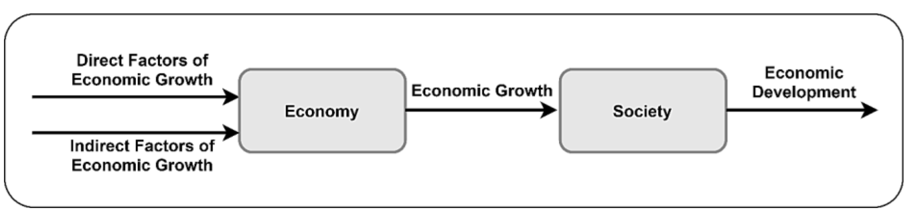
2.2. Economic growth factor classification scheme

The main factors that foster economic growth have been considered in different ways by economists. For example, economic growth factors have been associated with how these factors influence economic growth, either directly or indirectly[12] in terms of their effects on real GDP growth. There are several economic growth factors, groupings and sortings. These factors, as inputs into economic growth and development processes, have been organized into two broad categories (Boldeanu and Constantinescu, 2015):

1. **Direct economic growth factors** – for example, *human resources* (increasing the active population, investing in human capital); *natural resources* (land, underground resources); *capital formation*; and *technological advancements*; and
2. **Indirect economic growth factors** – for example, *institutions* (financial institutions, private administrations, etc.); *the size of the aggregate demand*; *saving rates and investment rates*; *efficiency of the financial system*; *budgetary and fiscal policies*; *migration of labour and capital*; and *efficiency of government.*

This robust economic growth factor classification scheme describes the groupings of economic growth factors based on common characteristics identified in relation to their direct and indirect effects on real GDP growth. Figure 1 depicts this relationship:

Figure 1. Economic growth factor classification scheme. Source: Composed by the author.



[12] Researchers have often sorted factors of economic growth by grouping them into tangible and intangible, qualitative and quantitative, economic and non-economic, extensive and intensive, and so on and so forth. These gradations and differences in factor sorting can be attributed to the differences in researcher views in relation to the problem of economic growth.

In Figure 1, the factors of economic growth are inputs into the economic growth process, where the economy and society remain important elements in this process. The outputs are economic growth typically measured at GDP per capita, and economic development, measured broadly in terms of the welfare of the population of a country.

Economists initially focused on direct economic growth factors, particularly in the early stages of economic growth and development research. The challenge then was the robustness of the indirect economic growth factors since their measurability in terms of direct impact on GDP growth was in contention. The debate about which factors should be considered indirect factors of economic growth has equally been long standing. Perhaps Spengler's (1957:42; 2013) view of direct economic growth factors in economic development seems most comprehensive:

> The strictly economic factors governing economic development are variously classified, herein they are collected and treated under three heads. In category I are assembled (1) the main physical agents of production-labor force, reproducible wealth, or capital, and provisionally nonreproducible wealth (land and natural resources) – and (2) applied technology. Under category II are included mechanisms and other circumstances which dominate the allocation of agents of production and finished goods and services (price system, extent of market, division of labor, inter-sector balance and aggregate demand, etc.). In category III are grouped (1) the major decision-makers and (2) the environment of economic decision. The role played by factors included in these categories vary with the degree of backwardness of economies.

Todaro (1994:100; 2000) presented three major direct factors necessary for economic growth in (1) capital accumulation, which includes all *investments in land, physical equipment and human* *resources*; (2) *growth in population and growth in the labour force*, and (3) *technological progress*.

Hunter (1957;57) provided examples of indirect economic growth factors in economic development. He said:

> These variously include such items as the need for a generally educated population, the necessity for land reform, and an adequate legal structure, etc. The treatment of such factors, as non-economic, as the term preconditions seems to imply, leaves the resultant economic theory extremely sterile because of the overwhelming importance in the real live world of these non-economic factors.

In Hunter's view, the effect of these indirect growth factors is intangible and "non-economic" since their measurability (quantitatively) in terms of impact on real GDP growth has been in contention. For example, the effects of informal institutions, culture, and governance and others considered the "institutional order" on economic growth are difficult, if not impossible, to measure or quantify. Hoselitz (1957;29), in clarifying indirect economic growth factors, which he saw more as preparatory and foundational for economic growth, puts it succinctly:

> We may consider that from the point of view of providing an explanation of the process of economic growth, the main functions of the preparatory stage are the changes in the institutional order, especially in areas other than economic activity, which transform the society from one point in which capital formation and introduction of modern economic organization of capital and the introduction of production processes appear as natural concomitants of general social progress.

Jary and Jary (1991;138) affirmed that culture is an indirect economic growth factor and described *culture* in relation to economic growth as:

> The human creation and use of symbols and artefacts. Culture may be taken as constituting the way of life of an entire society, and this will include codes of manners, dress, language, rituals, norms of behavior and systems of belief.

These indirect "non-economic" growth factors started to be acknowledged more with the works particularly of Lewis (1955). Ayres (1962), Mauro (1995), Rodrik (1999) and Acemoglu (2002) have highlighted the role of institutions[13] in economic growth and development processes, which Hoselitz (1957) had referred to as the "institutional order". Policy tends to focus on GDP per capita because it is more closely related to social welfare objectives.

Productivity growth has been considered a major driving force of economic growth in the economics literature. Hulten (2001) affirmed that what is common to economic growth in terms of growth in the long run is the productive capacity of an economy, and also that over the long term, economic growth should be accounted for by factors which impact on productivity growth, either directly or indirectly. Wei, Xie and Zhang (2017), cited the contributions of Fan et al. (2003) about the Chinese economy and the concept of productivity:

> As well as extensive growth in firms and augmented input use, knowledge growth and productivity improvement [growth] are key drivers of economic growth. [....] It is estimated that sectoral productivity increases, and structural change accounted for 42 per

[13] Acemoglu, Johnson and Robinson (2004) in their paper "Institutions as the fundamental cause of long run growth" developed the empirical and theoretical case that differences in economic institutions are the fundamental cause of differences in economic development of nations. See Acemoglu, et al. (2004)

cent and 17 percent of economic growth, respectively, during 1978–95.

Those factors which have accounted for productivity growth over time include both direct and indirect economic growth factors. For example, in the Solow (1956) neoclassical growth theories, *technological progress*, captured in total factor productivity (TFP), makes a persistent contribution to economic growth. In later endogenous growth models, *investment* (especially investment in innovation) is seen to drive technological progress; therefore, investment in innovation to drive technological progress has an impact on growth in the long run as well as the short term. Ancillary *firm activities* have been considered important factors of economic growth given their contribution to productivity growth. Next is the *business environment*. Factors in the business environment, such as infrastructure, the efficiency of markets, market incentives, taxation and regulation affect the productivity of firms and the efficiency of the economy as a whole. Investment in infrastructure affects the costs to firms of accessing resources and markets, and market conditions affect firm incentives to invest, be enterprising and innovate. On the demand side, factors of economic growth can be accounted for by *consumption* over time – household consumption, government consumption and business investment. On the supply side, *sectoral shares* come in. A broad-based shift in the structure of an economy from manufacturing to knowledge-based services are important signals. Another important supply-side factor of economic growth is one of *unbalanced growth*. The growth rate in surrounding regions has been seen to have an impact on the rate of regional growth (Mankiw, Romer and Well, 1992; Asteriou et al., 2011).

The problem of economic growth has been identifying which factors have evidenced a causal impact on economic growth, whether they are direct or indirect economic growth factors. Do all economic growth factors determine economic growth? The argument has been made that economic growth factors with evidenced causal impact on economic growth and development processes could be potential determinants of economic growth. For this, Durlauf (2005) in his work, identified 150 economic growth factors in the literature, based on numerous empirical studies, which he referred to as "determinants of economic growth". He added that the findings from the research he observed may have been logical and compatible with economic growth theories, yet could be misleading and diversionary, given that these studies were conducted at specific points in time and conclusions were drawn based on several country-specific dynamics. Durlauf (2005) further warned that using regressions or other statistical methods alone without considering the heterogeneity of factors underlying the economic development of countries could be misleading.

Factors of economic growth differ for each country context; therefore, both direct and indirect economic growth factors have been analysed based on country-specific circumstances. Some countries with similar or the same economic structures and characteristics do not develop in the same way or at the same pace. Therefore, the question of which growth factors have evidenced a causal impact (i.e. determinants) in which countries suffices. This suggests that country-specific dynamics are hard to agglomerate or decipher in other contexts. Chirwa and Odhiambo (2016) made a case by conducting a qualitative narrative appraisal of existing empirical research literature on key factors of economic growth in developing and developed countries and concluded that in (1) **developed countries**, economic growth was determined by *physical capital, fiscal policy, human capital, trade, demographics, monetary policy* and *financial and technological factors*. Meanwhile, for (2) **developing countries**, the determinants of growth include *foreign* *aid, foreign direct investment, fiscal policy, investment, trade, human capital development, demographics, monetary policy, natural resources, reforms, and geographic, regional, political, and financial factors.* Ostensibly, it is far more complicated to classify factors associated with developed and developing countries because of country-specific contexts than their direct or indirect effect on GDP growth.

In view of the research problem of this work, an analysis of 30 research papers was conducted by the author (See Appendix 1). These papers were published between 2000 and 2019 and sought to identify determining factors of economic growth in multiple countries.[14] The analysis revealed that twenty-four papers (about 79%) had focused on varying economic growth factors, while four papers sought to establish an association between *financial sector development* and economic growth, while the remaining two focused on *foreign direct investments*. The most significant observation was that the factors studied as inputs into the economic development process were predominantly direct economic growth factors, measured quantitatively for their direct impact on GDP growth. Additionally, the determining economic growth factors for each of these groups of economies were different at different periods of time.

To summarize, the factors of economic growth are vast in the literature. Several researchers have developed several ways of sorting and grouping economic growth factors in terms of country-specific contexts and dynamics (such as developed and developing country contexts); and whether they have had evidenced causal impact on economic growth (a.k.a. determinants), which Durlauf (2005) alerted as diversionary and misleading. The most distinctive

[14] These countries are considered to have modern economies. Modern economies are associated with Endogenous Growth Theory, which is associated with American economist, Paul Romer (1990). A central proposition of Endogenous Growth Theory is that, unlike land and capital, knowledge is not subject to diminishing returns.

classification is in terms of their impact on economic growth and economic development processes, either directly or indirectly. Factors which drive productivity growth have been identified as having direct effects on long-run economic growth and development. **For different countries and different periods, the determinants of economic growth have been substantially different.**

2.3. Innovation- and technology-led economic development framework

Before delving into the analysis of major concepts important to this dissertation, it is necessary to clarify the use and representation of important concepts to avoid any terminological misunderstanding, given the nature and volume of the research literature in this vast economics research stream.

The problem of innovation- and technology-led economic growth also raises the question of the driving forces that determine growth in an innovation- and technology-led economy. In the innovation- and technology-led economy, economic growth factors are specified as **innovation- and technology-led economic growth factors**. Factors with evidenced causal impact are specified as **innovation- and technology-led economic growth determinants** in this dissertation.

First, the innovation- and technology-led economy is a "knowledge-based economy[15]" in this dissertation. The concept of the knowledge-based economy has evolved over time in the consideration of new growth theories[16] such as endogenous growth

[15] The knowledge-based economy is defined by the International Telecommunications Union and OECD (2015). Some scholars argue that the knowledge-based economy is not a new phenomenon. (See Carlaw et al., 2006; Metcalfe and Ramlogan, 2005; Smith, 2002 and Harris, 2001)

[16] Gualerzi (2002) has done an extensive analysis in his paper "*Is New Growth Theory Endogenous*". See References.

theories.[17] Central to this economy is the dependence on knowledge and intangible sources of productivity and power to boost economic growth. For that reason, the **innovation- and technology-led economy** is understood in this dissertation as **an economy where the production, use and management of a country's resources by economic agents (individuals, businesses, organizations and governments) are associated with processes that involve predominantly, knowledge accumulation, technological innovation and human capital development**. In this sense, it is important to account for how innovation scholars have considered the knowledge-based economy.

One of the key proponents of the knowledge-based economy was Romer (1986). In his seminal contribution, Romer (1986) argued that the "underlying source of per capita growth of a country is the accumulation of knowledge".
Some scholars have emphasized the complexities associated with the knowledge-based economy. For example, Brinkley et al. (2012), Liu and Chen (2003), and Hui (2007) acknowledged that building and maintaining a knowledge-based economy is a complex and difficult undertaking, "itself only one step toward building a genuine innovation ecosystem." Goedhuys (2007) clarified what the innovation ecosystem constituted.

> At the foundation lies publicly supported research, which functions as the driver of original innovation in the long term. A second layer of innovation usually comes from industrial research and spin offs from existing large enterprises. Third, market development and firm creation are important for the innovation ecosystem to function (though markets are generally driven through forces of regulation, procurement or early adoption by risk-taking consumers and so should be seen as part of the

[17] Endogenous growth theories are covered more elaborately in the previous section.

interlinked innovation ecosystem rather than as a standalone phenomenon)

Kumar and Van Welsum[18] (2013) describe a framework for the knowledge-based economy and how it is connected with economic growth. Their work provides a path from knowledge accumulation to economic growth. Gacksatter et al. (2014) confirmed the core constituents in the knowledge-based economy and wrote:

> Increasingly, economists recognize that knowledge-based innovation is a major driver of competitiveness. That requires a powerful knowledge base, often centered on technology and innovation, as an important precondition for building and developing a genuine innovation economy.

In this work, developments emanating from the innovation- and technology-led economy will be referred to as innovation- and technology-led developments. In this regard, **innovation- and technology-led developments**[19] are specified as **technological, spatial, economic, occupational, and cultural improvements in the quality of life and living standards of a population in a country, resulting from innovation- and technology-led economic growth at a specific point in time**. These five dimensions are presented in the Glossary.

The concept of innovation- and technology-led economic development is represented in this work in the sense of Hirschman (1958), as a "transformation process". Innovation- and technology-led economic development results from innovation- and technology-led economic growth (Suparmoko, 2016; Ramayani, 2012; and

[18] Kumar and Van Welsum (2013) described the pathways of knowledge in an economy and depicted the creation, acquisition, dissemination, and utilization of knowledge in a knowledge-based economy.

[19] Webster (1995)'s definition of the "information society" components are adopted; the ITU referred to these as "information society dimensions".

Sukirno, 2015). In this work, the most important distinction between innovation- and technology-led economic growth and innovation- and technology-led economic developments is in terms of measurability. Innovation- and technology-led developments refers to the broader scope of dimensions already defined in the innovation- and technology-led economic development framework; while innovation- and technology-led economic growth is one of the measured indicators, in terms GDP growth, that will be used in measuring innovation- and technology-led developments in this dissertation.

Another important concept that ought to be clarified is economic innovation. **Economic innovation** will be understood in this dissertation as **a process which reformulates the economic growth model of a country so that intangible innovation- and technology-led economic growth factors such as knowledge accumulation, technological innovation and human capital development are positioned as forces at the centre of the innovation- and technology-led economic growth model.**[20]

This section has provided definitions for important concepts used in the dissertation by providing a basic structure of how terminology is engaged. In the author's view, these definitions amply cover the complexities that these important concepts are likely to pose in the dissertation. Definitions of basic concepts are presented in the Glossary.

[20] In the innovation- and technology-led economic growth model, inputs are innovation- and technology-led economic growth factors, outputs are innovation- and technology-led economic growth and innovation- and technology-led economic development. The main assumptions are that knowledge accumulation, technological innovations and human capital development are endogenous to the economic growth model.

2.4. Innovation- and technology-led economic growth factors

Given the results of the analyses so far, the author selected a number of economic growth factors, which are analysed in the following sections. It is important to note that the selected economic growth factors (1) have been well-researched in economics literature as having evidenced causal impact on economic growth and development in specific periods, in different country contexts, and (2) as postulated in this work, the selected factors have an established intimate connection with the innovation- and technology-led economy, where knowledge accumulation, human capital development and technological innovations are crucial to stimulating economic growth.

These selected growth factors, it is suggested, when pursued at the country level, inform a knowledge-based economy founded on country-level innovation-led growth strategies. The growth factors selected for analysis in the dissertation are:

Direct economic growth factors:

1. Research and Development (R&D) expenditure
2. Number of patent applications
3. Human capital development
4. Technological innovations
5. Regional innovation capability

Indirect economic growth factors:

6. ICT infrastructure
7. Innovation policy
8. Technology governance

Now, the rationale for the selection of the factors is that: knowledge is accumulated through investment in R&D activities, (therefore, R&D expenditure) which is triggered by ideas. R&D activities result in technological innovations. These lead to an increase in the number of patents per capita. Patents increase profitability by providing monopoly power to inventors (entrepreneurs) (Turedi, 2016; Zhang, 2014), which impacts greatly on technological innovations. Imported and local innovations are important in this process. To get the best from R&D activities, skilled people (human capital development) with the requisite competencies are needed. Hanushek et al. (2009) emphasized the link between education and economic growth. These are considered core factors in driving economic growth in the innovation- and technology-led economy.

The economic growth factors with significant impact on innovation- and technology-led developments include ICT infrastructure, which is considered critical to the accumulation of knowledge, and in that, data generated from informational activities and jobs are processed into information, which together with other insights develop into a knowledge repository. Subsequently, there are those factors such as innovation policy and technology governance. The importance of policy and governance arrangements in the innovation- and technology-led economy goes beyond coordination but also ensures the judicious allocation of resources to drive growth.

These growth factors are defined as follows:

- **Research and experimental development expenditure (R&D)** comprises expenditure on creative works undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of the stock of knowledge to devise new goods or services.

- **Number of patent applications** refers to the number of applications submitted to a national patent office to be granted exclusive rights for an invention.
- **Human capital development** refers to the development of knowledge, skills, competencies and other attributes embodied in individuals or groups of individuals acquired during their life and used to produce goods, services or ideas in market circumstances.
- **Technological innovations** comprise new or significantly improved products (goods or services), processes, new marketing methods or new organizational methods.
- **Regional innovation capability** refers to innovativeness at regional level as a consequence of networked cooperation in a regional innovation system, which sets demands for new kinds of regional innovation policy applications and economic growth rate, eventually promoting the convergence of regional economic developments. **Economic convergence** on the other hand refers to the fact that the growth rate and level of a country's per capita output are negatively correlated, which results in a gradually declining trend for the economic gap between countries in a region.
- **ICT infrastructure** is a composite of information technology equipment such as computers and related hardware, communications equipment such as digital telephone networks, mobile phones, internet capability, internet servers and fixed broadband and related technologies and computer software and services required for the existence, operation and management of the knowledge environment at the country level. It is used in this work as network

configurations that work and are responsible for social re-configuring.

- **Innovation policy** is the interface between R&D policy and industrial policy and aims to create a conducive framework for bringing ideas to market.
- **Technology governance** is the steering (controlling or guiding) between the different sectors of the development of technology at the country level.

2.5. Direct innovation- and technology-led economic growth factors

Direct economic growth factors are considered the main factors in economic growth. In innovation- and technology-led economies, research and development expenditure, patents, human capital development, innovation and technology, and regional innovation capability are direct factors of economic growth. These are analysed as follows:

2.5.1. R&D expenditure

The literature suggests that R&D can be performed and/or funded by the business enterprise sector, government, higher education and private non-profit organizations. Starting with the pioneering work of Griliches and Mansfield in the late 50s and early 60s (Griliches, 1964; Mansfield, 1965), a large literature has developed in which R&D expenditures are considered investments in a stock of knowledge, which depreciates. A large literature has considered this stock of knowledge a determinant of productivity (for surveys of this literature, see for example Griliches (1995), Hall (1996), Hall, Mairesse, Mohnen (2010)). Besides serving as a measure of innovation input, R&D can also be considered as a way to assimilate knowledge so as to be better able to absorb outside knowledge. In this regard it is like an investment in education to increase the absorption capacity. This dual aspect of R&D investment has been articulated by Cohen and Levinthal (1989). The R&D model is an endogenous growth model (Aghion and Howitt, 1992; Grossman and Helpman, 1991; Romer, 1990). In this sense, R&D allocates resources into two sectors: (1) the goods-producing sector; and (2) the knowledge-producing sector. Ha and Howitt (2007) show evidence in favour of the Schumpeterian fully endogenous growth models, whereas Bloom, Jones, Van Reenen and Webb (2017) illustrate the declining productivity of R&D in a number of research fields (Montmartin and Massard, 2017).

Lichtenberg (1992) investigated the relationship between growth and R&D expenditures in both public and private sectors of 74 countries for 1964–1986 and reported that there was no relationship between growth and R&D expenditures in the public sector, but R&D expenditures in the private sector affected growth positively. The relationship between R&D activities and economic growth was addressed by Gittleman and Wolff (1995) using panel data covering 1960 to 1988, such as real GDP per capita, R&D expenditures, the number of scientists per R&D, and the number of engineers per R&D activities. Their findings revealed that R&D activities accounted for growth only in developed countries but did not account for growth in low-income underdeveloped countries. Braconier (1973) did a similar test. Mehran and Reza (2011) also performed a comparative examination of the effect of R&D expenditures on economic growth in underdeveloped countries and OECD countries. Samimi and Alerasoul (2009) found that R&D expenditures in fact did not contribute to growth in developing countries because such expenditures were low in Turkey. Another study on Turkey by Altin and Kaya (2009) found that there was no relationship between the variables tested in the short run, but that R&D investments were a cause of economic growth in the long run.

Gykye (2012) performed a similar test using a Cobb-Douglas production function to examine the influence of R&D investments on the socio-economic development of sub-Saharan African countries and found that a rise of 1% in R&D investments contributed to economic growth in the countries by 0.326%.

The earliest panel data analyses for a relatively large number of countries were performed by Coe and Helpman in 1995. They studied 22 countries in the period 1970–1990. Park (1995) studied 10 OECD countries from 1970 to 1987 and provided evidence that domestic and foreign productivity growth is positively related to domestic private investment in R&D. Coe and Helpman (1995) provide support for a positive relationship between total factor productivity (TFP) and R&D stocks, including both a country's own and that of its trade partners. Engelbrecht (1997) assessed the robustness of Coe and Helpman's results, adding the human capital variable to their model. Their findings are consistent with the original results, although the estimated coefficients for R&D were smaller. Guellec and Van Pottelsberghe de la Potterie (2004) used panel data for 16 OECD countries over the period 1980–1998 to examine whether R&D – carried out by the business sector, the public sector and foreign firms – is positively related to TFP. Their results suggest that all types of R&D are significant factors of productivity growth, although the impact of business R&D increased while the impact of public R&D decreased over the period analysed. The authors also discuss why the effect of public R&D on output might be hard to capture directly in empirical analyses. Finally, Ang and Madsen (2011) considered the role of R&D in the growth experiences of the six Asian miracle economies from 1953 to 2006. Their results provide strong evidence that economic growth was driven by R&D intensity over the period analysed.

Groth (2005) has posited the argument that research and development may be too little or too much. The further argument has been that public research and development expenditures are mainly aimed at generating basic knowledge that is used in later stages by the business sector to create technological innovation. However, Guellec and Van Pottelsberghe de la Potterie (2004) highlighted that a large part of government-funded research and development is aimed at specific sectors that do not affect productivity, and that it is highly possible that there is no direct link between public research and development and economic growth. As mentioned earlier in this work, concerns have been raised by other scholars about the inefficiency of resource allocation, including research and development funding. It is argued that an insignificant relationship may exist between government funded research and development and economic growth. According to the OECD (2007), capital accumulation, adoption of technologies developed abroad and reforming the industrial structure are possible ways that new member states of the EU could catch up.

2.5.2. Number of patent applications

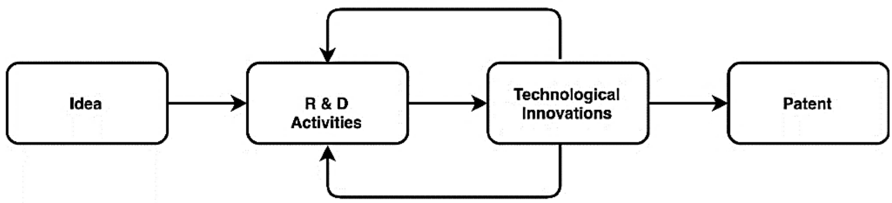
As patents are considered more the end-product of R&D activities, many studies have combined R&D expenditure and number of patent applications in research studies. For example, Saygili (2003), Zhang (2014) have all conducted studies into effect of R&D and patents on economic growth and reported favourable results. Hall, Jaffe and Trajtenberg (2005) compared the effect of R&D, patents and citations on the market value of firms and found that a percentage point increase in the R&D/assets ratio leads to a 0.8% increase in market value, that an extra patent per million dollar of R&D boosts market value by about 2%, and an extra citation per patent boosts it by over 3%.

For studies on the relationship between patent applications and economic growth, Crosby (2007) found that patent applications had a positive effect on labour productivity and economic growth in Australia. Sinha (2008) also investigated the relationship between the number of patents granted and economic growth in Japan and South Korea, and reported that there was no relationship between the two variables in South Korea, but there was a two-way causality relationship between them in Japan. Ortiz (2009) performed a regression estimation on cross-sectional data from 23 countries covering the period 1820 and 1990 and determined that there was a strong and positive relationship between the number of patents per person and per capita income in the long run. Other studies include those by Josheski and Koteski (2011), Saini and Jain (2011), Guo and Wang (2013) among others.

What has also been examined is the link between patents and R&D, one version of the so-called knowledge production function (Griliches, 1990). Patents can be very useful for estimating R&D spillovers. There are two ways in which this can be done. The first is to measure the spatial correlation of firms in the patent space; in other words, the vector positions of firms in patent classes. This idea goes back to Jaffe (1986). The idea is that the more firms patent in the same or in close patent classes, the more they perform similar research and benefit from each other's research. The second way patents can be used in connection to R&D spillovers is by way of patent citations.

The role of R&D in the growth process has been discussed in the literature since the 1980s alongside endogenous growth theories. Several studies have been conducted to establish this causality link (Romer, 1986; Grossman and Helpman, 1994). Second, patents are another important indicator of technological innovation (or development); that is, the capacity to create technological innovations in a country. According to the literature, there is a close relationship between R&D expenditures and patents, which are defined as the right of the owner of an innovation to produce, sell or import the idea or product they own within a period. This relationship is illustrated in Figure 2.

Figure 2. The emergence process of a patent. Source: Composed by author based on Türedi (2016).



From Figure 2, while R&D activities lead to an increase in patents through creating innovations, patents increase profitability by providing monopoly power to inventors and encourage R&D activities. Therefore, it is possible to say that an effective patent system enhances productivity and accelerates economic growth by contributing to technology production and transfer, the spread of technical knowledge, the expansion of economic activities, and the rise of national and international competitive power, while encouraging R&D activities (Zhang, 2014: p. 507–508).

In regard to patents, it has been argued that due to the cost of patenting, only the most economically valuable inventions are patented in most new EU countries catching up with the old EU countries. Arundel and Kabla (1988) observed in their studies that these low patent levels may be related to the cost of applying for a patent in terms of actual fees as well as the relative market-size-per-unit application cost, and the different industrial structure of the new and old EU countries. Typically, patent trolling has been ascribed for the lack of correlation between patents and economic growth. Boldrin and Levine (2012) describe trolling as behaviour where patenting is purely an anti-competitive strategy; where firms seek patents not to produce innovation but to extort patent fees from competitors.

2.5.3. Human capital development

The economic concept of human capital was incorporated into mainstream economic analysis and research from the 1950s. During this time, it became apparent, when empirical economic research was applied to concerns about economic growth and about income distribution, that major defects existed not only in the understanding of each but also, in the way it was thought about.

The key question of how human capital is the source of a nation's wealth and productivity, as being the skill of its people, takes on further meaning in the contemporary literature, particularly regarding innovations. In the views of Ellwood (2001), Jorgenson and Ho (1999), DeLong, Goldin and Katz (2002), since the 1980s, the quality of the workforce has stagnated, or its growth has dramatically slowed. The works of Thirlwall and Pacheco-Lopez (2017: 210) have asserted that improvements in education and skills can increase productivity and earnings of labour, adding that the capacity to absorb and use physical capital may be limited by many factors, including investment in human capital. They therefore suggested that there is a close association between education and the mainsprings of technological progress. According to Jones and Romer (2010:235), rising levels of human capital per capita could make the average individual better at discovering and sharing ideas. The World Bank, for example, reviewed the educational priorities of China and reinforced that a positive correlation exists between education and economic growth. The review concluded that "the link is strengthening with increasing globalization, competition for markets and dependence of economies

on knowledge and information. Skill is replacing other factors as the basis for competitive advantage in the global economy; the economic strength of a nation will become more dependent upon its ability to develop, utilize and manage its human resources." World Bank report (1999:9 and 2013). Continuous improvement in productivity growth has become the primary mechanism for promoting economic growth in contemporary times. According to Jones and Romer (2010: 241), the rising supply of highly educated labour tilts technical change in its own direction. Human capital development involves not merely the transmission and embodiment in people of available knowledge, but also the production of new knowledge, which is a source of innovation and of technical change, which propels all factors of production.
In this regard, the concept of human capital is analysed, first in relation to education, second, as a factor of production and third, in relation to technology.

First, **human capital and education**: The contribution of school education to this discussion has been interesting so far in the economics literature. For example, investment in school education and its importance has been recognized since the days of Smith (1923-1790), as a type of private or social investment that gained considerable rigorous conceptual and statistical examination in terms of analyses of the evidence of costs, returns and rates of return on education. The argument is that the costs of education borne by the student or their parents, is exclusive of the forgone earnings – the loss of what the student could have earned if they had spent the school years in gainful employment. The conclusion is that forgone earnings are the largest components of schooling costs. Schultz (1961) and Welch (1970), cited in Conte (2006) proposed that education promotes the adjustment to technological change in many of their studies of agricultural production activities. Therefore, education is suggested to improve human capital development in this sense, and as a consequence also knowledge and innovation.

Second, **human capital as a factor of production**: The traditional trinity of factors of production contained land – view as fixed, “original and indestructible”, labour – measured in numbers and hours, and capital – restricted to tangible plants and equipment, which were later extended. The notion of a quantity of land as a fixed factor of production was discarded when it was realized that the measurement of labour in manhours was entirely inadequate (Schultz, 1961). The quality and behaviour of people is increasingly recognized as accounting for differences in income levels among countries (Mincer, 1981). Indeed, it appears that indexes of human capital, such as average levels of education, are more strongly correlated with average income levels across countries than measures of physical capital per unit of labour. Some critics of human capital theory question the inference that education increases productivity from the observation that it increases wages, and still others assert that schools do not affect skills but serve merely as a filter to sort differences in ability, which exist independently of schooling. However, this argument is contradicted by research, in that studies of empirical production functions have shown that not only differences in wage rates but differences in productivity are related to differences in education and training of the labour force across states, regions and over time (e.g. Maia, 2018; Konings, 2010). Such studies have also shown that the development of a significant and broadly-based level of human capital in a nation is a lengthy process, which involves profound social and cultural changes. The framework of an aggregate production function makes it clear that the growth of human capital is both a condition and a consequence of economic growth. The growth of human capital, as a factor of production, it is suggested, raises the marginal product of physical capital, which induces further accumulation of physical capital, and thus total output, both directly and indirectly.

Third, **human capital and technology**: the effects of human capital growth and some of its causes can be described in the framework of an aggregate production function, in which technology is fixed. There are few contrary views about the growth of technology as the ultimate force which propels all factors of production by increasing their productivity. It is helpful to distinguish between the stock of human capital as a standard factor of production and the stock of knowledge as the source of technology. Human capital activities involve not merely the transmission and embodiment of available knowledge in people, but also the production of new knowledge which is the source of innovation and of technical change. Without new knowledge, it is doubtful that larger quantities of existing physical capital, more widespread education and health would create a continuous growth in productivity on a global scale. Scholars such as Basu, Fernald, and Shapiro (2001) considered technology use in relation to productivity. More recently, McGuckin, Streitwieser and Doms (1998) looked at the effects of technology use on productivity growth by examining the use of advanced (computer based) technologies at two different points in time. It can be concluded that human capital produces the stock of knowledge and interfaces with technology to do this.

2.5.4. Technological innovations

Technological innovations occur, according to Branscomb (2001), when a new technical idea is implemented successfully in agreement with the assertions of Schumpeter (1934); and Aghion and Howitt (2015). By the way, Rogers (1962; 1975; 1986; 2003) popularized the notion of innovations and their diffusion in a social system in his seminal works.

The innovation performance of countries has become an important input for government policy making. Existing measurement frameworks include: (1) Summary Innovation Index (SII) – used in the European Union. The SII is a metric derived using a linear aggregation method from a set of components that are grouped into three main categories – Innovation Enablers, Firm Activities and Innovation Outputs (Eurostat, 2016); and (2) Global Innovation index (GII) – a more international measurement framework. The GII is a composite metric that covers 128 economies (2016 version). The GII has two sub-indices (Cornell, 2016): Innovation inputs and Innovation outputs with several sub pillars such as Institutions, Human Capital and Research, Infrastructure, Market Sophistication and Business Sophistication, Knowledge and Technology Outputs and Creative Outputs.

According to Birchall et al. (2011), there is no consensus or single agreement on what should be measured and how it should be measured, while Muller et al. (2005), had suggested selecting the indicators carefully. At a country level, measurement of innovation performance is based on a comparison of numerous science, technology and innovation indicators or complex composite indicators such as the GII and SII. These have been criticized by scholars such as Godin, (2003), Grupp and Schubert, (2010), among others. Their arguments have been that aside from technical processing problems, the selection of composite indicators in these country-level innovation measurement frameworks is not based on an explicitly defined innovation model that would justify their use and explain relations among components, their weights and impact on economic performance (Godin, 2003; Grupp and Mogee, 2004). They further note that these measurement frameworks do not lead to the clear identification of a country's strengths and weaknesses. Schibany and Streicher (2008) add that these indicators lack the economic institutional context, for that matter.

The innovation discussion begs the question of the measurability of the innovation performance of countries. To the International Monetary Fund (IMF), "there are no agreed definitions of digital sector, product or transactions, let alone the digital economy." The IMF further notes that the "digital economy" is sometimes defined narrowly as online platforms, and activities that owe their existence to such platforms, yet, in a broad sense, all activities that use digitized data are part of the digital economy and that rather than attempting to focus on the broad digital economy, most research studies and reports have focused on a digital sector which comprises the producers at the core of digitization: online platforms, platform-enabled services, and suppliers of ICT goods and services.

In recent studies of the concept of the digital economy, such as that by Brynjolfsson (2002), Tapscott (1996) and Mesenbourg (2001), it is considered a new benchmark for measuring the sustainable development of nations. They argue that in measuring the digital economy, innovation is central. In several contributions to the scope of the digital economy, the scope has been narrowed to e-commerce and internet-related and online platforms, as noted earlier. The challenge has been that the so-called digital economy (which is not decoupled from digital sectors) is becoming increasingly inseparable from the functioning of the economy as a whole. Notwithstanding, there are several measurement models and frameworks for assessing technological innovation, as conducted by various global and regional institutions. These include: (1) Networked Readiness Index of Global Information Technology Report series of the World Economic Forum: which measures the propensity for countries to exploit the opportunities offered by information and communications technology. (2) International Telecommunications Union ICT Development framework: published annually since 2009, is a composite index that until 2017, combined 11 indicators into one benchmark measure. It is used to monitor and compare developments in information and communication technology (ICT) between countries and over time, and (3) OECD/Eurostat: The Oslo Manual for measuring innovation, which defines four types of innovation: product innovation, process innovation, marketing innovation and organizational innovation (OECD, 2018).

It can be concluded that technological innovation is the implementation of innovations, which are diffused to generate productivity growth. However, the challenge has been in measuring the innovation performance of nations. Although, several innovation frameworks, albeit requiring further improvements, provide a sense of country-level innovation performance.

Now, technological change has been identified as an important source of economic growth in the literature. Invention and innovation are the sources of technological change according to Schumpeter (934;39) and can create knowledge that might spill over to entities that were not responsible for the original creation according to Hall and Rosenberg (2010:6). Arrow suggested that this calls for policy to encourage the appropriate level of investment in these activities. In this sense, governments need to encourage innovation by investing more in research and development activities. Technological change has been accelerating in several sectors in many countries: in transport, space technologies, telecommunications and more. Technological frontiers have been known to support the process. Key contributing factors include collaboration between firms and scientific institutions, including universities, and the strengthening of incentives, as suggested by the literature. The issue of measurability has been under debate since the 1930s, yet many different mechanisms have been adopted globally for assessing country-level development in terms of technological change. Of significance is the Networked Readiness Index (NRI).

2.4.5. Regional innovation capability

Regional policy applications are enabled by the European Union region as a block, and therefore members of the Union are afforded an opportunity to pursue policy programmes and projects that are geared at harmonizing innovation capability in the region. The concept, as posited in this work, stresses innovativeness at regional level, and networked co-operation in a regional innovation system. As an example, the Regional Innovation Strategy (RIS), funded under Article 10 of the European Regional Development Fund (ERDF), was intended to ensure development of an adequate level of 'social capital' in the less-favoured regions of the EU, and complement the massive investments in infrastructure. This is a means of promoting economic development, higher productivity and competitiveness and thereby narrowing existing disparities in the regional EU block. Morgan et al. (2004) have outlined extensively the regional innovation strategies and the challenges for less favoured regions in their works. When applied, regional innovation capability results in regional economic convergence.

The concept of economic convergence is derived from the neoclassical growth model proposed by Solow (1956). Economic convergence refers, in this work, to the fact that the growth rate and level of a country's per capita output are negatively correlated, which results in a gradually declining trend for the economic gap between (units of analysis) countries in the same region. The concept of economic convergence is used in relation to different countries within a region, such as the EU region in this dissertation. The literature suggests that economic convergence can be divided into two categories: α convergence and β convergence. α convergence refers to the variance of per capita income in different regions or the fact that the discrete coefficient tends to decrease over time. Macroeconomics focuses on β convergence, and this form is mainly demonstrated by the fact that the economic growth rate of backward areas is higher than that of developed areas, resulting in the per capita income of the former gradually catching up with the latter.

The empirical studies of convergence in advanced economies (e.g. Baumol, 1986; Barro and Sala-i-Martin, 1992) show that the per capita income level of different states in the United States, for example, and those of developed countries have converged. Baumol (1986) examines convergence from 1870 to 1979 among 16 industrialized countries. He posited based on his work that convergence has shown itself strongly in the growth of industrial nations since 1870. The basis for his conclusions was on a regression of growth from 1870 to 1979 on the initial productivity level. This assertion was disputed by De Long (1988) as largely spurious, in that, there were sample selection issues and measurement errors. Romer (1986) and Rebelo (1991) made similar assertions about the lack of convergence across economies. The arguments have been varied. More recent works, such as Dowrick and Nguyen (1989), Barro and Sala-i-Martin (1991 and 1992), Mankiw, Romer and Weil (1992), Lightenberg (1992), among others, investigated the sources of growth and convergence. The overall evidence in their analysis weighs heavily in favour of the neoclassical growth models, strengthening their validity. The convergence hypothesis was rejected following the studies of Bernand and Durlauf (1995) after they studied 15 OECD countries using time series techniques. They defined the convergence of countries to mean that each region has identical long-run trends, either stochastic or deterministic, while common trends allow for the proportionality of the stochastic elements. Meanwhile, many studies have suggested that the majority of developing countries fail to narrow their per capita

income gap with developed countries. In the case of Carrington (2003), their test results show that there is no convergence among European countries in terms of per capita income.
Romer (1990) and many other scholars in the field have suggested that the level of human capital is an important factor affecting the rate of economic convergence. Empirical studies of convergence in advanced economies (such as that by Baumol, 1986; Barro and Sala-i-Martin, 1992) have shown that the per capita income levels of different states within the United States and those of developed countries have converged. Researchers, such as Romer (1994), Baumol (1986) and Barro and Sala-i-Martin (1992) have found that the majority of developing countries fail to narrow their per capita income gap with developed countries. Carrington's (2003) work shows that there is no convergence among European countries in terms of per capita income.

2.6. Indirect innovation- and technology-led economic growth factors

In the following subsections, ICT infrastructure, technology governance and innovation policy will be analysed as indirect growth factors.

2.6.1. ICT infrastructure

To leverage the vast array of productivity and power that could be generated from information and communication technology, core infrastructure is needed to connect the user with various repositories, in order to build the knowledge hub in the innovation- and technology-led economy. Socio-technical theorists such as Rip and Kemp (1995;1998) refer to this as network configurations that work and are responsible for social re-configuring. In this sense, such an infrastructure serves as glue to connect several information systems together, seen more as an integrating factor in a network of computers, part of the technical subsystem in the sociotechnical supra system.

When Feldman and Florida (1994) considered geographic sources of innovation, they concluded that once these geographic concentrations of infrastructure are in place, they enhance the capacity for innovation, as regions come to specialize in particular technologies and industrial sectors. Geography organizes this infrastructure by bringing together the crucial resources and inputs for the innovation process in particular places.

Czernich, Falck, Kretschmer and Woessmann (2011) conducted a study using purely quantitative methods focused on physical infrastructure, more specifically, the effect of broadband infrastructure – enabling high-speed internet – on economic growth. Their study revealed that for every 10-percentage point increase in broadband penetration, annual per capita growth was raised by 0.9–1.5 percentage points. Koutrompis (2009) confirmed that a significant causal positive link existed between broadband infrastructure and economic growth. The scope of the research covered 22 OECD countries based on data collected for the period 2002–2007. Another scholarly work exploring infrastructure by Esfahani and Ramirez (2003) showed that the contribution of infrastructure services to GDP is substantial and in general, exceeded the cost of the provision of those services. Their work also shed light on the factors that shape a country's response to its infrastructure needs.

Roller, Lars-Hendrik and Leonard Waverman (2001) investigated how tele-communications infrastructure affects economic growth using evidence from 21 OECD countries over a 20-year period. They examined the impacts of telecommunications developments. They found a significant positive causal link, especially when a critical

mass of telecommunications infrastructure was present. Meanwhile, studies such as that by Munnell (1992) support the argument that much of the decline in productivity that occurred was precipitated by declining rates of public capital investment but remained inconclusive about the direction of causation between public investment and output growth in their empirical works.
It can be concluded that ICT infrastructure is important in knowledge accumulation and productivity growth. Yet how the concept has been studied over time has been to quantify expenditure or find ways to represent its effect on economic growth. ICT infrastructure is considered an ultimate factor in this work, with a likely indirect influence on economic growth, also with a direct impact on economic innovation.

2.6.2. Innovation policy and technology governance

The creation and application of new knowledge and technology is a major contributor to overall human wellbeing and economic growth. Policies are essential in this development drive, and therefore also innovation policies. The concept of technology governance is based on the notion of innovation and of techno-economic paradigm shifts according to the theories of Schumpeter (1934) and other scholars.

The EU, for example, in the European Council Conclusions in 2010, set a strategy towards the improvement of conditions for research and development through increased investment in research and development (R&D) to 3% of GDP at country level. Lundvall (1994) reaffirmed that the fundamental resource in the modern economy is knowledge, and accordingly, the most important process is learning. The role of knowledge in innovation processes is strongly emphasized by the literature (Dosi, 1997; Metcalfe, 1998; Nelson, 1995), as well as by the literature on the knowledge-based economy (Cowan, et al., 2000; Lundvall, 1994). Ferdows and Rosenbloom (1981) in their review of technology policy and economic development from the Asian perspective, cautioned that the process of growth in a country is a complex system, interacting with all elements of a society and that it is “necessarily artificial to lift a single element, such as technology, out of that context”. While clearly making this point, Ferdows et al. (1981) mentioned that an explicit policy for technology and in particular one that defines the complementary roles to be played by imported technology and indigenous learning, is a useful part of economic policy for any developing economy, adding that the significance of technological change for economic development cannot be downplayed. They concluded that “technological change is the only component of productivity improvement that is not subject to natural limits”. They also noted that the advancement of knowledge (which they classified as the source of technological change) can be attained either through importing technology or learning from local practice. On technology policy, it is important to know that the choice for a government from an array of technology policies lies between one designed to influence the level of imported technology or the rate of learning in a country. The goal is to define a rough concept of relative emphasis on which direction to go. Rammel and van den Bergh (2003) emphasized that traditional economic approaches are inappropriate for dealing with the dynamics of structural and adaptive changes in economic systems. This is in line with a growing body of literature analysing the potential of evolutionary economics to explain sustainable development and environmental policies including the work of Kemp et al. (1998), Norgaard (1994), and van den Bergh and Gowdy (2003). According to these contributions, an evolutionary foundation for sustainable development policies should account for concepts such as adaptive behaviours, evolutionary potential, diversity, path-dependence and lock-in. Within this framework of analysis, the notion of transition policy has emerged which goes beyond the traditional policy approaches in the fields of environment, energy and technology, encompassing elements of all these policy fields, involving technology policy, the development of knowledge at individual and public levels, behavioural change and alterations in organizations (including networks) as well as institutions (including markets) (Kemp 1998; Rotmans et al. 2001; van den Bergh et al. 2037). Rotmans et al., for example, defined transition policy as the stimulation and management of learning processes, involving different actors and multiple dimensions, preserving the variety of policy and technological options and motivated by a long-term policy objective (Rotmans et al. 2001). In this evolutionary context, policy and institutions appear different from the viewpoint of traditional economics in the sense of Metcalfe (1995).

To Lundvall and Borras (1997), and Zenker (2000), the European regional innovation systems require region-specific policies to achieve the collective learning among participants in innovation. In most European countries, Laredo and Mustar (2001) suggest that the two main foci of regional innovation policies have been 'acting on the higher educational landscape' and 'innovation capabilities' through establishing proximity networks and intermediary structure (see also Turpin & Garrett-Jones, 2002). The recent innovation systems theory, technological innovation systems (TIS) theory and multilevel socio-technical systems (MLS) theory have been highlighted by scholars such as Markard and Truffer (2008b) as two strands of research that are important to studies, such as this work.

Policy in this section interfaces between R&D and technological development policy and industrial policy to create a conducive framework for the steering of different sectors of technology development in a country. Arusha (2009) tested the role of governance on economic growth for 71 developed, developing and transition countries between 1996 and 2003, and demonstrated that countries with strong governance grow faster compared with those with weak governance.

While on the concept of governance, it has been proven in many empirical studies that resources allocation issues are a major block to economic growth. Murphy et al. (1993) and Mauro (1995) argued that corruption has a negative effect on economic growth by affecting innovation and other start up activities and may reduce productivity (Svensson, 2003).

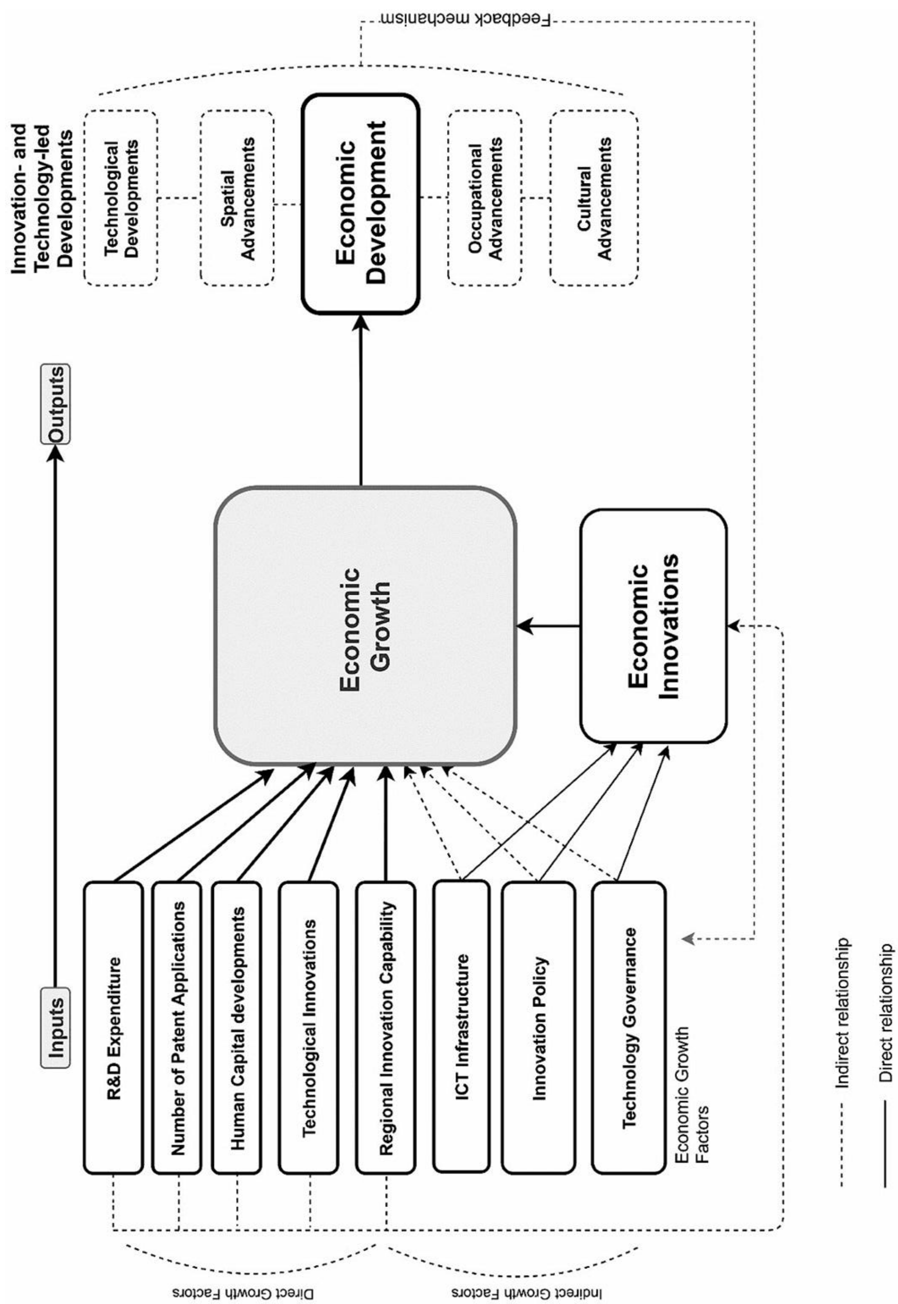
Therefore, technology policy goes hand-in-hand with technology governance to create the necessary environment for innovation to thrive in the innovation- and technology-led economy. These are considered foundational to coordinate resources and direct growth in the right direction.

2.7. Conceptual model of innovation- and technology-led developments

The factors selected for analysis (See section 2.4) were elaborated in sections 2.5 and 2.6. Prior studies on these economic growth factors were reviewed in relation to economic innovation, productivity growth and economic growth. However, there are some economic growth factors that not only have a direct influence on economic growth but also play a somewhat mediating role. Accordingly, a **Conceptual Model of Innovation- and Technology-led Developments** is proposed in Figure 3, which depicts the very complex relationship leading to what is analysed in this work.

To reiterate, direct economic growth factors have a direct effect on economic growth, yet an indirect relationship on economic innovation. Meanwhile, indirect economic growth factors are at the centre of the coordination process and have a direct influence on economic innovation and indirect effect on economic growth.

Figure 3. Conceptual model of innovation- and technology-led developments.
Source: Composed by the author.



As can be seen from Figure 3, the complex relationship depicted is such that the selected growth factors in the innovation- and technology-led economy serve as inputs that are at the centre of the reformulation of the economic growth model. These factors of economic growth stimulate economic innovation, which changes the economic growth model pursued at the country level, in the sense that these economic growth factors make for process and economic efficiencies, hence productivity growth, which are reflected in the broader economic development at the country level. To further clarify, the **conceptual model** is premised, in this work, on the following grounds:

1. In the innovation- and technology-led economy, **knowledge** of all forms is crucial and nations that develop and manage their knowledge assets effectively tend to perform better. Therefore, national strategies should put a central emphasis on the innovative and knowledge-creating capacities of an economy. Innovative activities, including immaterial investments in R&D creates opportunities for further investments in the productive capacity of a nation.
2. Within this knowledge-based economy, **innovation** continues to play a central role, in that, at the macro level, there is a substantial body of evidence that innovation is the dominant factor in national economic growth and international patterns of trade. At the micro level, and within firms, R&D is seen as enhancing the capacity of firms to absorb and make use of new knowledge of all kinds, and not just technological knowledge.
3. Schumpeter (1934, 1939) argued that **economic innovation** is at the heart of economic growth. Schumpeter proposed a list of the various types of economic innovation, including, introduction of a new product or qualitative change in an existing one; process innovation which is new to an industry;

opening of new markets; development of new sources of supply of raw materials or other inputs; and changes in industrial organization.

4. While **patents** are the end-product of ideas, R&D activities and technological innovations, they are granted as protection for an invention. Technological innovation and digitalization on the other hand emphasize implementation, which suggests the application of "protected" ideas.
5. **ICT infrastructure** is considered more prominently by socio-technical scholars. One of the very relevant parts of the technological ecosystem is infrastructure. This includes the physical hardware used to connect computers to other computers and users, software and other peripherals, in a sociotechnical system.
6. **Innovation policy and technology governance** have been seen as necessary frameworks to drive policy programmes and projects in order to transform an economic model into a fully digital, innovation-led one.

While all this is the case, the broader scope of the development dimension is activated. In that, as a result of these factors of economic growth, other areas of social and environmental sectors are activated and influenced by the effects on the inputs in the system. These are referred to as Innovation- and Technology-led Development. These are broader benchmarks for measuring the other impacts not captured adequately as informational or knowledge inputs, in the economic growth and development measures.

2.8. Chapter summary

The Chapter 2 analysed important scholarly works related to growth factors in the innovation- and technology-led economy. While there are many factors of economic growth and several concepts about how nations grow, the analysis contributed to the selection of growth factors categorized into two strands: (1) Direct factors – R&D expenditure and number of patent applications; human capital development, technological innovations, regional innovation capability and economic convergence; (2) Indirect factors – ICT infrastructure; innovation policy and technology governance. To connect the concepts together and to describe the relationships between the processes involved in the economic development of a country, a **Conceptual Model of Innovation- and Technology-led Developments** is suggested. This serves as a blueprint to guide the entire research process and expected outcomes. In addition, the analysis yielded support for the **assertion that there is no existing theory about determinants (as evidenced causal factors) of economic growth at the country level – these determinants are country and period specific.**

3. RESEARCH PROCESS AND METHODS

This chapter presents the research process and methods. Methodological, ontological, and epistemological issues and their complexities are carefully analysed. Section 3.1 presents a general philosophical framework for the dissertation. Section 3.2 analyses the choice of process-tracing methodology. In the section 3.3, the rationale for the choice of explaining-outcome variant of the process tracing methodology and the research design choices are highlighted. Section 3.4 analyses how the selected methodology is operationalized in the dissertation, and the research strategy, process and methods are carefully outlined. Sections 3.5 and 3.6 set the hypotheses and provide alternative choices and counterfactual outcomes.

3.1. General philosophical framework

According to Carter and Little (2007), methodology provides the justification for the research method used, while in the view of Morgan and Smircich (1989) and Noor (2008), the choice of method for a study is highly dependent on the nature of the research problem and phenomena under review. Given the nature of the research problem and research questions (see Chapter 1), the overarching research philosophy is **Interpretivism**. The interpretivist philosophy is appropriate in this work because according to Myers M. D. (2008), interpreting elements of the study and integrating human interest into it are important in this philosophy, which assumes that access to reality is constructed through language, consciousness, shared meaning and instruments. The choice of interpretivism in this work means:

- interpreting subjective meanings and social phenomena

- a focus on the details of the case or cases selected for the research, the reality behind the details in the situation, their subjective meanings, and motivating actions

It emphasizes qualitative analysis and makes the use of multiple methods possible to reflect different aspects of an issue, usually focused on meaning or creating an understanding of a situation. This philosophical choice agrees with the paradigm of **constructivism** in the study. In this, human interests are the main drivers of science which aims to increase general understanding about a specific situation from data (see examples: Witty, 1998; Lincoln and Guba, 2000; Schvanult, 2001; Neuman, 2000).

Although this dissertation is developed around a multi- and inter-disciplinary grounding, it belongs within **Innovation Management** research more closely. In this stream, the discussion of concepts, methods and designs that facilitate the evolution and development of innovation for national and global development is a key driver.

The **postmodernist paradigmatic perspective** as proposed by Grenz (1996:8) is appropriate in this dissertation because, in his view, the postmodern perspective is a "community-based understanding of truth" in that truth always possesses a local nature and context, which is also at times subject to change.

3.2. Why methodology of process-tracing

With the selected philosophical armoury, the **process-tracing** methodology is selected for this work. Process-tracing as popularized by Beach and Pedersen in 2013 has been engaged in the social sciences and is commonly defined by its ambitions to trace causal mechanisms (Bennett 2008a, 2008b; Checkel 2008; George and Bennett, 2005). The essence of process-tracing is for scholars to go beyond merely identifying correlations between dependent and independent variables so as to unpack the causal relationships between the variables and study the causal process – causal chain and causal mechanisms linking concepts between them. A causal mechanism, in the sense of Beach et al. (2013) and Glennan (1996:52) is a "complex system that produces an outcome by the interaction of a number of parts." The methods are tools used to study causal mechanisms in a single case research design. The questions about what types of causal mechanisms to trace and to what degree process-tracing case studies can be nested in broader mixed-method research designs have been left unanswered so far in the methodological literature (Beach et al., 2013:3). This murkiness and likely methodological pitfall, it has been advised, can be cleared through the application of one of the differentiated variants of process-tracing: (1) theory-testing; (2) theory-building; or (3) explaining-outcome variants. For each of these variants, a checklist is prescribed in view of the conceptualization of causal mechanisms, case selection, the operationalization of empirical tests and evaluating empirical evidence to make causal inferences. A causal inference here refers to the use of observed evidence to make conclusions about causation, understood as either patterns of regularity (mean causal effect) or mechanistic relations. Meanwhile, a causal mechanism refers to a theorized system that produces outcomes through the interactions of a series of parts that transmit causal forces from independent variable to dependent variable. Each part of the mechanism is considered an individually insufficient but necessary factor in a whole mechanism, which together produces the outcome (dependent variable).

(1) Theory-testing process-tracing deduces a theory from the existing literature, and then tests whether evidence shows that each part of a hypothesized mechanism is present in a given case, enabling within-case inferences about whether the mechanism functioned as expected in the case, and whether the mechanism was present as a whole.

(2) Theory building process-tracing seeks to build a generalizable theoretical explanation from empirical evidence, inferring that a more general causal mechanism exists from the facts of a particular case.

(3) While the differences between the first two variants are conspicuous, the third variant, explaining-outcome process tracing attempts to craft a minimally sufficient explanation of a puzzling outcome in a specific historical case. In many ways, explaining-outcome combines both the first and second variants to produce an explanation of an outcome.

The literature has revealed that ontological issues could pose further methodological challenges in process-tracing, notwithstanding the variant choice. For example: (1) whether we should understand a causal relationship in a sceptical, neo-Humean fashion, where causality is seen purely in terms of regular association (regularity); (2) whether causality refers to a deeper connection between a cause and effect (e.g. a mechanism); (3) whether causal relations should be understood in a deterministic or probabilistic fashion; (4) whether mechanisms should be understood as operating solely at the micro/actor level or whether macro/structural mechanisms also have a reality of their own; as well as (5) epistemological debates about whether we can directly observe causal mechanisms or whether we can only observe the implication of their existence, among other arguments. Yet, clear-cut answers are not provided. Palier (2005, 2010), Steinlin and Trampusch (2012) and Trampusch (2014) have warned that the decision about which process-tracing variant to apply is part of the research design, with a propensity to vary with further knowledge of the case under review.

Hall (2003: 374) has said, "the fundamental assumptions scholars make about the nature of the social and political world and especially about the nature of causal relationships within that world" is **ontology**. To Hall, "Ontology is ultimately crucial to methodology because the appropriateness of a particular set of methods for a given problem turns upon assumptions about the nature of the causal relations they are meant to discover."

Regarding the use of various data sources, Thies (2002) and Kreuzer (2010) recommend following general guidelines to avoid the effects of selectivity and a bias in the use of primary and secondary data sources. They further point out that measurement validity should be improved using context-specific domains of observation, context-specific indicators and adjusted common indicators requiring thoughtful data collection, in agreement with Adcock and Collier (2001).

In relation to counterfactual analysis and mental experiments, George (1997: 7) has said a good safeguard for process tracing is to analyse a series of events in sequence or parts of a causal chain considered as a mental and cognitive construction in cases where there are reality gaps. Falleti and Lynch (2009) noted that the researcher in process-tracing should investigate carefully when the process started and when it ended. According to Moravscik (2014: 665–6), what he refers to as 'transparency revolution' across quantitative and qualitative research, which encompasses 'data transparency', 'analytic transparency', as well as 'production transparency' should be evident in a good process tracing research. Most process tracers have warned that, when a causal interpretation must be made of a single case, process tracing is not often attainable using statistics alone but the more angles the case is addressed from, the better the causal interpretation.

3.3. The choice of explaining-outcome process-tracing and case selection

In agreement with Beach et al. (2013), the **Explaining-Outcome** variant of process-tracing is selected as method, strategy and research design for this dissertation. Explaining outcome process-tracing is case-centric and cannot be generalized to other situations. It is best suited to explain historical events. The goal of explaining-outcome process-tracing is to come to a “sufficient” explanation about an outcome. This variant is more akin to a holistic historical study. In this, theoretical mechanisms are combined with non-systematic (case-specific) elements. Beach and Perdersen (2013) advised that when using the explaining-outcome variant, looking for already existing research that has investigated the outcome, or that has delved into aspects that may be relevant to explaining the outcome are foremost. Then assembling (and combining) a number of plausible theories and adapting them to the context of the case, and investigating these theories in the case, adapting the theoretical framework and gathering evidence until a minimally sufficient explanation is reached should inform the research design choice. To craft a research design for this dissertation, several actions are undertaken. The first of which was to **lay out the theoretical expectation** in the form of a review of relevant literature, conceptualize and develop a framework to guide the study and to clearly spell out underlying assumptions and sources (See Chapter 2).

Second, **to give direction to the research** through a robust research design, in the sense that causal interpretations are extracted via an iterative process of tracing cause of effect. Finally, to **identify the types of data necessary for testing** and which methods to employ to arrive at the necessary inferences.

Estonia was selected as a single case in order to conduct an in-depth within-case analysis: to trace growth factors, assuming that they are founded in innovation-led, knowledge-driven economic strategies, which could account for why Estonia has been economically successful in leveraging ICTs over the period from 2000 to 2015 in order to craft a "minimally sufficient" explanation of whether the selected factors of growth, (see Chapter 2) indeed are what determines economic growth in the innovation- and technology-led economy. Secondary data sources were considered most appropriate with no need for primary sources, given the research design, problem and questions.

The choice of Estonia as a case country, is because over two decades, post re-independence in 1991, Estonia was touted as having made tremendous technological progress which enabled economic growth and accelerated national development. The period between 1960 and 1991 is considered a period of pre-study events, while from 2000 to 2015 is the main study period. Since Estonia joined the EU in 2004, data became more readily available for analysis, hence the selection of 2000 as the beginning of the study period. The period between 2005 and 2015 also constitute ten years within which Estonia enjoyed membership of the EU, therefore it is considered expedient to select 2015 as the end of the period for analysis. The 16-year period is considered adequate for the analysis in this work.

Estonia's population is relatively small and densely homogenous which enables exploratory works of this nature. Further, Estonia has been technologically successful, having weaned itself away from the Soviet Union starting in 1987, when it was a low technology country, to become an advanced technology country by 2015 in barely two decades. The reports of established global institutions that periodically measure the technological state of countries showed a marked departure between such reports on Estonia for the year 2000 and 2015. The International Telecommunications Union (ITU), and Global Information Technology Report (GITR) series and Networked Readiness Index (NRI) of the World Economic Forum (WEF) have provided prescribed global benchmarks to gauge the technological progress of countries and how they have leveraged Information Communication Technologies (ICTs) for economic growth and sustainable economic development. The economic records also showed marked differences in economic growth indicators over the same period. These peaked interest in Estonia as a case study for this dissertation.

Country reports covering the period 2000 to 2015 were gathered, including those from the INSEAD Global Information Technology Reports (GITR) series, the International Telecommunications Union (ITU) reports, the Human Development Report (HDR) series, United Nations (UN) reports, Organization for Economic Co-operation and Development (OECD) reports, Eurostat, World Development Indicators web portal, European Union (EU), WIPO, The Conference Board as well as local (Statistics Estonia, ministries and agencies of government) and other international institutional reports. These were gleaned for information that would assist the study in gaining some momentum. A detailed description of the constituents of selected reports which contents were leveraged, including the NRI reports and aggregation mechanisms, principles, indexes and sub-indexes can be found in these institutional reports.

The dissertation's empirical part **combines process tracing methodology with a case study research design** in agreement with Beach and Pedersen (2013) to analyse which causal pathways, mechanisms, timing of events, and policies best explain the economic growth and development of Estonia since 2000. The combined use of case study and process-tracing allows for the development of strong inferences on causal mechanisms that may explain the research inquiry. By combining the description of the events, causal pathways, and mechanisms, this process-tracing exercise converts historical narratives of Estonia together with observations from the data into causal explanations. The blending of case study and process-tracing methodology may allow robust explanations to be elaborated.

To investigate events in the study, an **abductive research approach** is adopted because explaining-outcome process-tracing aggregates two alternative paths – the inductive, case-specific level (theory-building) and the deductive causal mechanism level (theory-testing) or a combination of both – when building the best possible explanation of an outcome. With abduction, the question is when to stop the process of sifting through evidence to uncover a plausible sufficient causal mechanism that produced the outcome. No foolproof answer to this question is available in the literature yet.

The strategy is simplified to an extent that growth factors that are clearly related to the outcome of economic growth, which are simple in nature and testable are employed before more complex explanations are employed.

3.4. Operationalizing the process-tracing methodology with the Estonian case

Against this backdrop, **the process-tracing methodology is operationalized in the following steps**:

1. **Developing the Causal Sequence Framework** – Walder (2015) and Slater and Wong (2013) suggest that a visual depiction of the causal process helps to identify the variable(s) of interest. They also provide structure to allow the researcher to focus on the link between the explanation and the concerned outcome. This visually depicts the causal

process through which X causes Y such that all mechanisms could be identified. To Walder (2015), what matters is that these mechanisms are "collectively sufficient to generate the outcome." This is presented in the dissertation as a Conceptual Model (CM) of Innovation and Technology-led Developments (see section 2.7). It assembled interrelated concepts and how these could be operationalized in the dissertation. This conceptual level analysis is translated into the hypothesized mechanisms in this chapter.

2. **Developing and Specifying Hypotheses** – This includes establishing testable hypotheses. In this, the focus is not only on the theory of interest but to also juxtapose rival explanations that will be tested in agreement with Hall (2013), Rohlfing (2012) and Zaks (2017). Careful, analytically informed specification of the hypotheses into primary hypotheses and secondary hypotheses is crucial, based on the evidence to be presented, testability of the hypothesized mechanism and envisaged impact on the outcome.
3. **Identifying Alternative Choices/Events** – In this step of the process tracing, for each item in the causal sequence framework, a different possible choice or event is suggested. There must be some reason that the choice could have been made in another way or that event could have manifested differently.
4. **Identifying Counterfactual Outcomes** – Here, a counterfactual outcome is identified in the causal sequence framework. Counterfactuals are vital to process tracing, especially when no alternative cases are under consideration (Fearon, 1991). If there is no plausible theory-informed alternative outcome, then no real choice or event has taken place, hence process tracing provides little value. Slater and Ziblatt (2013) have suggested another approach in lieu of

counterfactuals, where controlled comparisons are used, where the case of interest is compared with empirical alternatives rather than a hypothetical counterfactual. Counterfactuals are used as heuristic devices that allow the researcher to identify hypothesized outcomes and thus potential data to collect.

The Alternative Outcome Choices and Counterfactual Outcomes are explored in this Chapter.

5. **Finding Evidence for Primary Hypotheses** – Here, data collection and evidence gathering takes place. Importantly, data collection should be designed to recognize that not all evidence types are the same, as suggested by Bennet et al. (2015), Mahoney (2012) and Rohlfing (2012). Some data, in their view, are necessary to establish causation, others are sufficient, but Collier (2011) recommends extensive discussion of each. It is important to also make clear expectations about the evidence types needed to support the main argument as well as negate the rival hypothesis (See Chapter 4).
6. **Finding Evidence for Rival Hypotheses** – In this step, for each choice node, the focus should be on an alternative explanation. This may require multiple iterations depending on the number of rival hypotheses. The objective is to dismiss as many explanations as possible, leaving only the most likely hypotheses (See Chapter 5).

Now, in connection with actions (5) and (6), Bennett (2010:210) based on the original works of Van Evera (1997, 21–32), suggested the application of process tracing to causal inference in terms of four empirical tests. These are process-tracing tests for causal inference. These tests are classified according to whether passing the test is necessary and/or sufficient for accepting inference. These also have implications for the rival hypotheses. For example, if a given hypothesis passes a straw-in-the-wind test, it only slightly weakens the rival hypotheses. Meanwhile, with a hoop test, it somewhat weakens them. For a smoking gun test, it substantially weakens them, while with a doubly decisive test, passing eliminates them. There are no definitive definitions of the elimination of a hypothesis in any case. In addition, careful, analytically informed specification of hypotheses is considered essential both in selecting and interpreting pieces of evidence, and in weighing them against one another. Therefore, background knowledge of the case is fundamental.

Based on these criteria, which guides the process-tracing exercise as suggested by Bennett (2010) and Colier (2011), Table 1 presents the four tests:

- **Straw-in-the-wind test** – these are empirical predictions that have a low level of uniqueness and a low level of certainty. These tests do little to update confidence in a hypothesis. Passing or failing are of little if any inferential relevance.
- **Hoop test** – involve predictions that are certain but not unique. Failure of such tests reduces confidence in the hypothesis but does not enable inferences to be made. They are sometimes used to exclude alternative hypotheses.
- **Smoking gun test** – in this test, passing strongly confirms a hypothesis, but failure does not strongly undermine it. This test has low or no certainty in their predictions.
- **Doubly decisive test** – is an empirical test that combines high degrees of certainty and uniqueness. In this, the evidence must be found or confidence in the validity of the hypothesis is reduced. At the same time, the test strongly

discriminates between evidence that supports the hypothesis and alternatives.

Table 1. Process tracing tests for causal inferences. Source: Composed by the author based on Bennett (2010).

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Sufficient for Affirming Causal Inference</td></tr>
<tr><td>No</td><td>Yes</td></tr>
<tr><td rowspan="4">Necessary for Affirming Causal Inference</td><td rowspan="2">No</td><td>Straw in the Wind</td><td>Smoking Gun</td></tr>
<tr><td>a. Passing: Affirms relevance of hypothesis, but does not confirm it
b. Failing: Hypothesis is not eliminated, but is slightly weakened
c. Implications for rival hypotheses:
• Passing slightly weakens them
• Failing: slightly strengthens them</td><td>a. Passing: Confirms hypothesis
b. Failing: Hypothesis is not eliminated, but is somewhat weakened
c. Implications for rival hypotheses:
• Passing substantially weakens them
• Failing: somewhat strengthens them</td></tr>
<tr><td rowspan="2">Yes</td><td>Hoop</td><td>Doubly Decisive</td></tr>
<tr><td>a. Passing: Affirms relevance of hypothesis, but does not confirm it
b. Failing: Eliminates hypothesis
c. Implications for rival hypotheses:
• Passing somewhat weakens them
• Failing: somewhat strengthens them</td><td>a. Passing: Confirms hypothesis and eliminates others
b. Failing: Eliminated hypothesis
c. Implications for rival hypotheses:
• Passing: eliminates them
• Failing: substantially strengthens</td></tr>
</table>

A combination of strategies were deployed in the empirical part of this dissertation, since process-tracing allows the engagement of multiple methods and strategies. These included: (1) **Quantitative methods**: econometric analyses, including linear regression, panel data analyses, spatial estimation, modelling and regression. (2) **Qualitative methods**: literature reviews and document analyses, and descriptive and interpretive case analyses (Eriksson and Kovalainen, 2011; Dudovskiy, 2018). Various tools were employed in data transformation, analyses and visualization. These included in no particular order: Microsoft Excel, R Programming language, Python programming language, EViews, Tableau Desktop software, Statistical Package for Social Sciences (SPSS) version 26, Geographical Information systems (GIS) resources and tools.

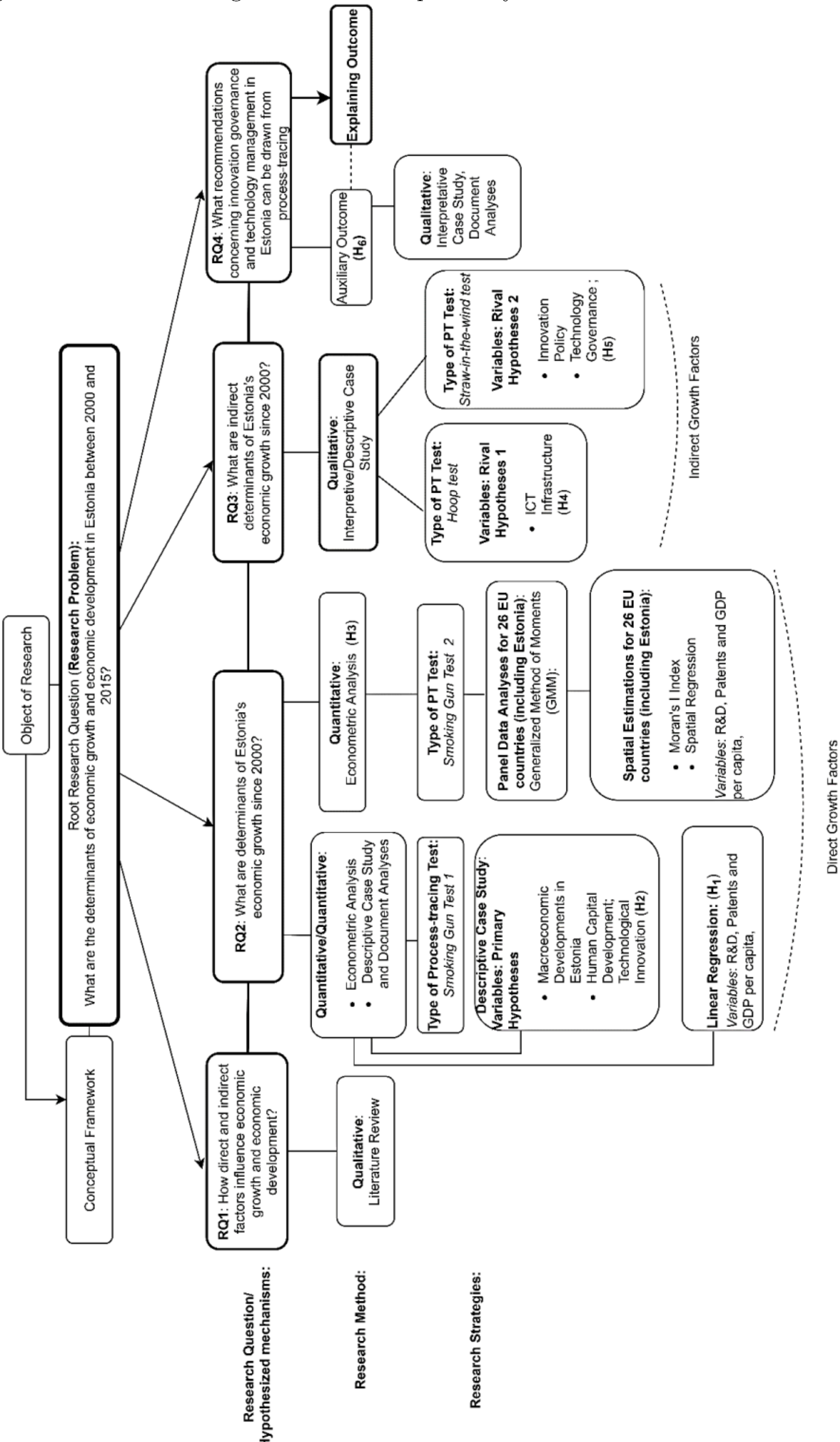
7. **Auxiliary-Outcome test** – to make well-informed inferences in the methodology, iteration is crucial. Therefore, as a further action in operationalizing the methodology, a secondary variable is introduced into the original causal sequence framework in the hope that it could influence the outcome significantly. This is tested as an Auxiliary outcome. A new hypothesis is introduced for testing in this connection. The results of this test are factored into the final analysis in this work (See Chapter 6).
8. **Explaining Outcome** – to arrive at the outcome, a conglomeration is made of all mechanisms encountered in this work. This is placed against new theories of growth and analysed in a quest to exhaust possible narratives that could influence the outcome again. The result of this iterative exercise is considered in Chapters 6 and 7.

Figure 4 summarizes the research design – which establishes the connections between the Root Research Problem, Research

Questions (See Chapter 1) and methodological applications. The hypothesized mechanism which depicts the causal process is provided in Chapter 2, as the rationale for these.

The smoking gun tests are conducted for H_1–H_3. Meanwhile for H_4, the Hoop Test was performed. For H_5, a straw-in-the-wind test was performed. The details are captured in Figure 4.

Figure 4. Research design. Source: Composed by the author.



The first research question (**RQ1**) introduces focus to the research, in that it narrows down the vast array of economic types and growth sources addressed in the dissertation by summarizing recent studies and results, and justifying why the selected factors of economic growth are considered. The second research question (**RQ2**) investigates the existence or otherwise of a causality link between the selected direct growth factors in the innovation- and technology-led economy and economic growth in Estonia during the study period. The third research question (**RQ3**) sought to establish whether the selected indirect growth factors could have facilitated the re-formulation of the economic growth model of Estonia, with innovation and technology as underlying drivers. The fourth research question (**RQ4**) investigated the notion that the economic growth trajectory and industrial mix had changed in Estonia and assessed the possible linkages between the causal mechanisms, inferences and interpretations, while putting forward possible recommendations for improved innovation governance and management.

To address **RQ1**, relevant literature is analysed to identify the factors of economic growth of nations and how they influence economic growth and economic development. As a result, a **Conceptual Model of Innovation- and Technology-led Economic Development** (Conceptual Model) was developed connecting the main concepts and variables of the study and serving as a framework to solve the causal puzzle. In this model, the relationship between the direct factors of economic development (R&D expenditure, number of patent applications, human capital development, technological innovation and regional innovation capability), indirect factors of economic development (ICT infrastructure, innovation policy, technology governance), economic innovation, economic growth, and economic development is analysed.

To address **RQ2** and **RQ3**, process-tracing tests to establish causal mechanisms are conducted. The respective research design consists of the following steps:

1. Developing the causal sequence framework for the causal process through which the selected growth factors cause economic growth.
2. Developing and specifying the hypotheses to be tested.
3. Identifying alternative choices and events in the causal sequence framework.
4. Identifying counterfactual outcomes.
5. Finding evidence for the primary hypotheses and also evidence for the rival hypotheses.

By combining the description of the events, causal pathways, and mechanisms, process-tracing converts historical narratives into causal explanations, which makes for a robust explanation about the outcome of economic growth in Estonia. Four tests are conducted based on a **Matrix for assessing the certainty and uniqueness of evidence** as prescribed by Beach and Pedersen (2013).

1. Straw-in-the-wind test
2. Hoop test
3. Smoking gun test
4. Doubly decisive test

The Matrix is used as a Method of Elimination and Decision Criteria in this work. Though subjective, the inferences and conclusions assert a degree of confidence in each part of the hypothesized mechanism, based on the evidence collected and tests applied.

To address **RQ4**, exogenous and endogenous pathways of Estonia's economic development are analysed, which will lead to policy recommendations concerning the development of the digital knowledge-driven economy.

3.5. Setting up hypotheses

Based on the methodological selection, the mechanisms in the conceptual model (see Chapter 2) are variables which collectively generate an outcome. This visually depicts the causal sequence framework and causal process in the dissertation. The methodology engaged requires that the hypothesized mechanism is clearly specified following the assembling of interrelated concepts. This was satisfied in Chapter 2 with the development of the Conceptual Model. Therefore, a relationship is made between X (independent variables) and Y (dependent variables), and therefore the discovery of the mechanisms that connect X and Y, in this Explaining-Outcome process tracing exercise.

For Beach et al. (2013), a variable is anything whose value changes over a set of units. Variable values can vary, and variables have an existence independent of each other, as each is, in effect, a self-contained analytical unit. Therefore, the **independent variables** in the study include:

- Research and Development expenditure
- Number of Patent Applications
- Human capital Development
- Technological Innovations
- Regional Innovation Capability
- ICT Infrastructure ("integrator" of information systems)
- Innovation Policy
- Technology governance

An **Intervening variable** in the sense of Seawright and Collier (2010:334) is a variable that is causally between a given independent variable and the outcome being explained. The Intervening Variable is:

- Economic Innovation

Meanwhile, a **Dependent Variable** (Outcome Variable) refers to a variable whose value is dependent on another variable. These include:

- Economic Growth (measured in Gross Domestic Product per capita) and Economic development
- Digital Economy, strategic innovation- and technology-led economic growth and development (Auxiliary Outcome)

In the empirical part of this dissertation, six hypotheses are stated for testing. These are divided into Primary Hypotheses – Direct Growth Factors and Rival Hypotheses – Indirect Growth Factors.

The **Primary Hypotheses** are:

- **H_1**: Research and Development (R&D) expenditure and the number of patent applications are positively associated with economic growth.
- **H_2**: Human capital development and technological innovations are key drivers of economic growth.
- **H_3**: Regional innovation capability has a significant positive effect on regional economic growth.

The **Rival Hypotheses** are:

- **H_4**: ICT infrastructure has a significant positive impact on economic innovation.
- **H_5** Innovation policy and technology governance have a positive influence on economic innovation.

The **Primary Hypotheses**, (Hypotheses 1–3) are considered highly testable and simple, given the weight of evidence in the literature in support of previous studies done in multiple contexts about the subject matter, in addition to the quantitative data and methods required to confirm or disconfirm them.
The second set of hypotheses are the **Rival Hypotheses** (Hypotheses 4 and 5). These are considered more complex, as theoretical expectations in connection to these are not well laid out in relation to the object of research, and the research problem of this dissertation.

Mahoney (2010, 125–31) suggested the use of another test by introducing an auxiliary variable, which was not part of the original causal sequence framework yet could provide valuable inferential leverage. Therefore, the hypothesis stated for testing in the **Auxiliary Outcome test** is:

- **H_6**: The Estonian digital transformation is characterized by "development-driven strategies", rather than by "strategy-driven development"

Hypothesis n, which is used as a weighted decision mechanism to evaluate the Alternative Hypotheses from Hypotheses 1–5, is stated as:

- **H_n**: Selected innovation- and technology-led economic growth factors are significant predictors of Estonia's economic development.

The levels of analysis in this work are organized as follows:

- Table 2 shows the relationships between the hypothesized mechanism for the **Primary Hypotheses**. In this, the levels of analysis will be divided into two parts, (1) domestic, which include internal factors expected to influence the outcome of economic growth, and (2) regional, which are considered external factors such as unbalanced regional growth. These represent competing explanations in operationalizing the variables in the hypothesized mechanism.

Table 2. Establishing causal relationship. Source: Composed by the author.

Economic Growth Factor	**Innovation promoting effects**	**Growth as**
Domestic: • Patent System and Enterprise R&D Expenditure • Human Capital Development, Technological Innovation	• Shifting growth models towards consumption, services, higher value-added manufacturing and innovation; Productivity • Accumulation of human capacity; Education and Learning; rapid in-country innovation diffusion	• Double-digit GDP growth rates and macroeconomic development • Increased Domestic Technology Absorptive capacity
Regional: • Regional Innovation Capability and Economic Convergence	• Conditional Convergence Hypothesis	• Regional Economic Convergence and Development

- Table 3 shows the relationships between the hypothesized mechanism for the **Rival Hypotheses**. Here, the levels of analysis are also divided into two parts, (1) domestic and (2) regional, which represent competing explanations in operationalizing the variables in the hypothesized mechanism.

Table 3. Competing explanations. Source: Composed by the author

Level of analysis	Key Players	Triggers of Change	Growth as
Domestic	Government, Leadership; decision-makers Institutional failure	Changes in policy; Internal Environmental factors	Instrument for growth policy
Regional	OECD countries, Soviet influence and competing agendas	External environmental factors; Competitive pressure; technological inertia	Regional development

3.6. Identifying alternative choices and counterfactual outcomes

As prescribed for the operationalization of the selected methodology for the hypothesized mechanism, alternative choices ought to be identified and counterfactual outcomes also developed. These also serve as mechanisms for the interpretation of causal inferences in the dissertation.

Hypotheses 1–3, the Primary Hypotheses, are considered highly testable. Therefore, alternative choices and counterfactual outcomes for these hypotheses are stated foremost:

- **Inference A1**: A positive relationship between R&D expenditure and the Number of Patent Application variables is interpreted as **exceptionally unusual** – establishing that the Independent Variables, R&D expenditure, and number of patent applications have a significant role in predicting the Dependent Variable – GDP per capita – and Economic Growth.
- **Inference A2:** Human capital development and technological innovation are interpreted as **exceptionally unusual** drivers of economic growth – establishing that human capital development and technological innovation are inextricably linked to the economic growth of a nation.
- **Inference A3**: Regional innovation capability is interpreted as **exceptionally unusual for** economic growth.
- **Alternative Inference $A1_1$**: R&D expenditure and the number of patent applications are interpreted as **somewhat unusual**, suggesting but hardly confirming the relationship with economic growth. The relationship is just a coincidence.
- **Alternative Inference $A2_2$**: Human capital development and technological innovation are interpreted as somewhat unusual, suggesting but hardly confirming the relationship with the economic growth of a nation.
- **Alternative Inference $A3_3$**: Regional innovation capability is interpreted as somewhat unusual, suggesting but hardly confirming the relationship with the economic growth of a nation.
- **Summary:** If R&D expenditure and number of patent applications are exceptionally unusual; human capital development and technological innovation are exceptionally unusual; regional innovation capability is exceptionally unusual, they are **smoking guns** that confirm Hypotheses 1–3. With a weaker interpretation that R&D expenditure and number of patent applications are somewhat unusual; human

capital development and technological innovation are somewhat unusual; regional innovation capability is somewhat unusual, so they are a straw-in-the-wind, that makes Hypotheses 1–3 more plausible without confirming it.

Hypotheses 4, a Rival Hypothesis, is considered as having low certainty and uniqueness. The alternative choices and counterfactual outcomes are that:

- **Inference**: With a stronger assumption based on the role and implementation of ICT infrastructure, that ICT infrastructure could have been instrumental in the events leading to economic innovation.
- **Alternative Inference**: With a weaker assumption about the role and implementation of ICT infrastructure, there is some doubt about the link to economic innovation but does not preclude it.
- **Summary:** With a stronger assumption, this is a Hoop test which fails $\mathbf{H_4}$; with a weaker assumption, it is a straw-in-the-wind test which casts doubt on $\mathbf{H_4}$**.**

For **Hypothesis 5**, another Rival Hypothesis, the alternative choices and counterfactual outcomes are:

- **Inference:** The question of whether innovation policies implemented and technology governance practices could have been influential in fostering economic innovation, but does not demonstrate this.
- **Alternative Inference:** With a weaker assumption, technology governance and innovation policy may not be influential in driving economic innovation but does not preclude it.
- **Summary:** These are promising contributions, a **straw-in-the-wind**, which lends weights to $\mathbf{H_5}$ but is not by itself a

decisive piece of evidence in Estonia's economic growth. The straw-in-the-wind favours **H_5** but does not confirm it.

In the weighted decision mechanism to evaluate the Alternative Hypotheses from H_1–H_5, the alternative choices and counterfactual outcomes are:

- **Inference:** The assumptions of H_1–H_3 suggest a strong relationship between economic growth determinants and the economic development of Estonia.
- **Summary for H_n:** The combined weight of H_5 – straw-in-wind; H_4 eliminated by hoop tests, strongly favours the assumptions that H_1–H_3 may be a smoking gun, providing strong evidence in support of the RP – and answering the RQs (see section 3.4) as a consequence.
- **Summary of Doubly Decisive Test:** Four (4) out of Five (5) tests provide inferences where the combined weight of evidence confirm H_1–H_5, suggesting but not confirming that they could be growth determinants for the sustained economic development of Estonia and of nations.

In testing the Auxiliary Outcome, the alternative choices and counterfactual outcomes are:

- **Inference:** The assumptions of H_6 suggest that Estonia's digital success story is a product of a development-driven approach rather than strategy-driven coordinated policy or bundle of programmes.
- **Alternative Inference:** With a weaker assumption, Estonia's accelerated digital transformation was based on a digital initiative arising from documented foundational policy and strategy implementation over the long term.
- **Summary:** These are promising contributions – a **straw-in-the-wind**, which lends weights to **the original outcome** but

is not by itself a decisive piece of evidence. The straw-in-the-wind favours $\mathbf{H_6}$ but does not confirm it.

3.7. Chapter summary

Chapter 3 analysed the philosophical, methodological and ontological complexities surrounding the choice of process-tracing as a methodology and the explaining-outcome variant as a research strategy, method and research design for this dissertation. The Chapter provides **a map of the empirical research process** and **how this will be operationalized** in connection with the Estonia case. This chapter's analysis serves as a guide for the dissertation, including the empirical parts in the ensuing chapters 4 and 5. The analysis in the chapter provides direction for the research process: including actions taken and expected outcomes (results) as a consequence.

4. FINDING EVIDENCE FOR PRIMARY HYPOTHESES AND INFERENCES

This chapter presents findings from data analysed using the matrix for assessing the certainty and uniqueness of evidence as proposed by Beach and Pedersen (2013). For this, smoking gun tests were conducted (see section 3.4). Section 4.1 and 4.2 present demographic and socio-economic information, and macroeconomic developments in Estonia, respectively. In section 4.3, a linear regression is employed to test $\mathbf{H_1}$, seeking to establish a causal relationship between R&D expenditure, number of patent applications and economic growth in Estonia as hypothesized. In sections 4.4 and 4.5, human capital development and technological innovation are analysed to establish whether the data submitted provides sufficient or necessary evidence in support of the smoking gun tests conducted. A descriptive case study method was engaged to test $\mathbf{H_2}$, seeking to establish whether human capital development and technological innovation are key drivers of economic growth in Estonia. In section 4.6, regional innovation capability is analysed for 26 EU countries, including Estonia, using panel data analysis with a view to establishing whether a significant correlation between economic growth rates and regional development exists across the selected countries in the EU region. This regional level analysis of R&D expenditure and number of patent applications is reinforced by per capita GDP geospatial data estimations and modelling to test $\mathbf{H_3}$, also seeking to establish a causality link between regional innovation capability and regional economic growth in the section

4.7. At the end of the analyses, inferences are made based on the evidence submitted. The analyses sought to answer RQ2.

RQ2: What are the direct innovation- and technology-led economic growth determinants of Estonia's economic development since 2000?

4.1. Demographic and socio-economic information of Estonia

The population of Estonia, on average, stood at 1.3 million and did not change much between 2000 and 2015 (see Figure 5). The total area is 45,336 km^2 with a population density of about 30 inhabitants per km^2. There are 79 local governments in Estonia with 15 towns and 64 municipalities. The number of local governments diminished substantially as a result of local government reform in 2017 (from 213 to 79). The official language is Estonian. However, English, Russian, Finnish and German are widely spoken as well. This has not changed significantly since 2000. Tallinn is the capital city. A summary of key events that took place in Estonia between 1900 and 2015 are appended to this work (see Appendix 2).

Figure 5. Population of Estonia. Source: Composed by author based on World Indicators.

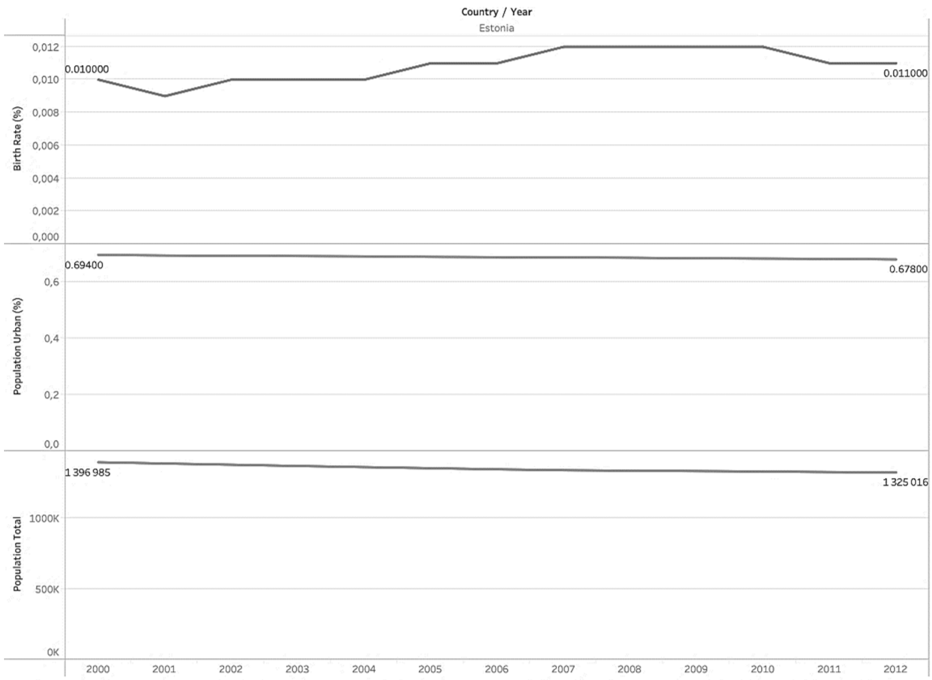
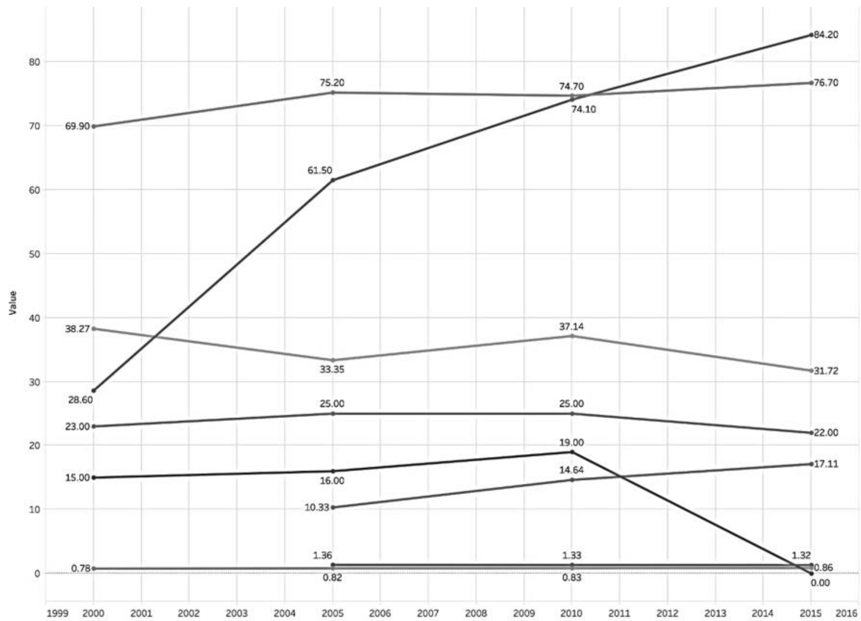


Figure 6 shows key socio-economic indicators. These include $C0_2$ emissions from fuel combustion, Freedom Index, GDP per capita, Human development, Internet users per 100 inhabitants, main telephone lines per 100 inhabitants, Networked Readiness Index placement and population of Estonia over the study period. While Estonia has enjoyed press and other freedoms since 1991, the number of internet users has increased from less than 20% to more than 80%. During the same period, $C0_2$ emissions have significantly dropped, all positive socio-economic signals. In terms of freedom on the net, Estonia ranked 2nd in 2015 and on Press Freedom 15th out of 197 countries. Estonia equally ranked well on many other global socio-economic indicators including economic freedom, doing business, networked readiness, corruption perception, competitiveness, prosperity and democracy (see Appendix 3).

Figure 6. Socio-economic indicators, Estonia (Five-year intervals). Source: Composed by author based on World Indicators data.

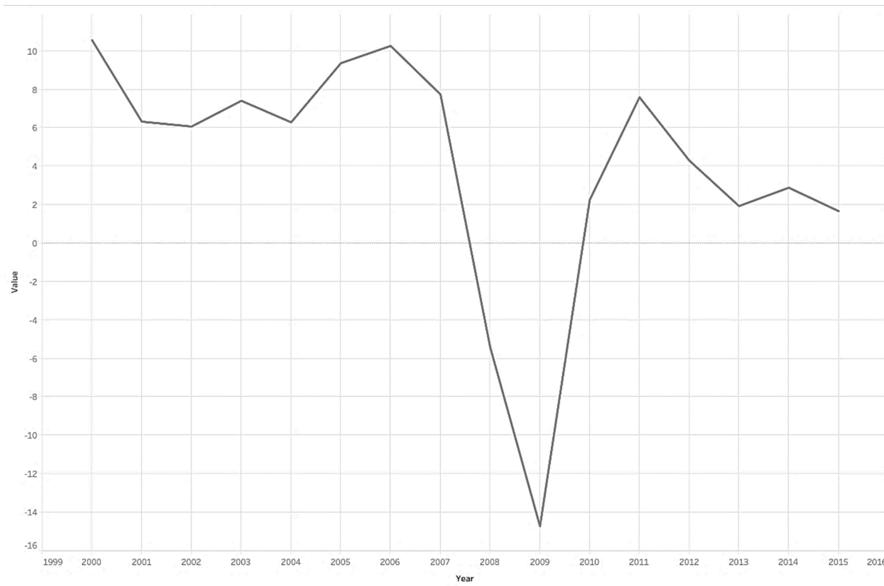


4.2. Macroeconomic developments in Estonia

The new growth path that Estonia has sought since 2000, is that broadly followed by today's advanced economies in earlier times. According to Maddison (1987), this path involves the substitution of tangible components such as land, labour and physical capital with intangibles such as knowledge, innovation and technology. Many countries, however, get stuck in that transition and fail over decades in their attempt to enter the high-income group of these advanced economies. Eichengreen (2011) refers to this circumstance as the 'middle-income trap'. In this transition process from a low-income to an advanced economy, some growth drivers such as shifting the economic growth model towards consumption, services, higher value-added manufacturing, and innovation are crucial. In the following subsections, the macroeconomic developments of Estonia are analysed in connection with this.

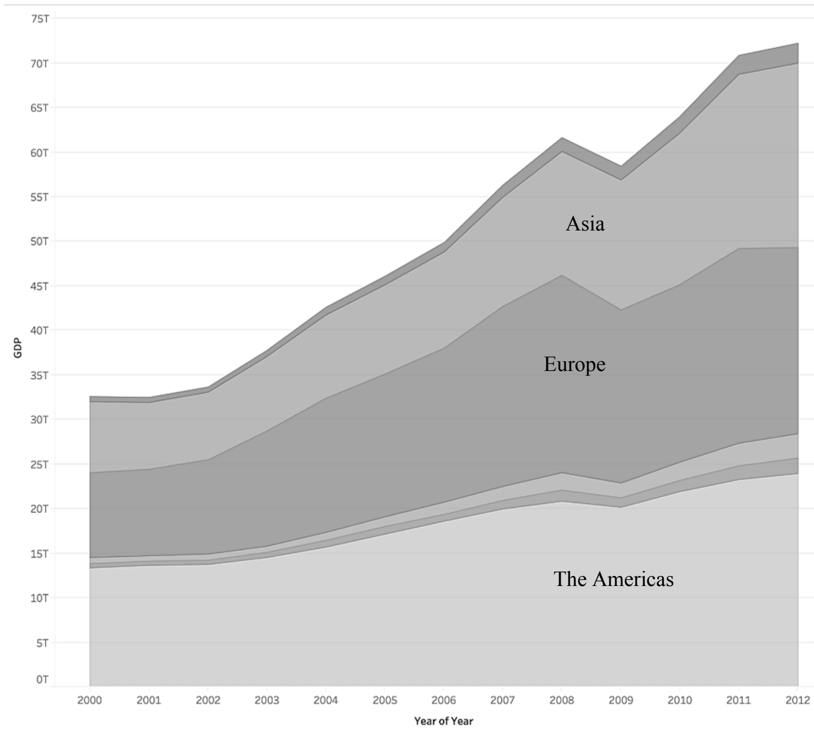
Estonia's economy grew consistently between 2000 and 2015. The steady growth trend from 2000 saw a nose-dive in 2008 during *the worldwide financial crises*. The Estonian economy grew at 1.1% in 2015 according to Eesti Pank (2016), Estonia's central bank. The Estonian economy saw an average growth of about 7% per year between the years 2000 and 2008 according to Statistics Estonia (2015), the national statistical authority of Estonia. This placed Estonia among the three countries in the EU with the fastest growing real GDP with then improved living standards and a GDP per capita inching up from 45% of the European Union (EU) average to 67% in 2008. This business-friendly situation saw a steep downward descent during the economic crisis in 2008. The GDP growth rate decreased 14.7% for 2009. Interestingly, by the second half of 2010, the annual GDP recorded had grown by 2.5% compared to the previous year. According to Statistics Estonia, the annual GDP increased by 1.1% in 2015, compared to the previous year 2014. In 2016, the annual GDP increased by 1.7% also compared to the previous year, 2015. For 2017/2018, economic growth stabilized at around 3%. The registered unemployment rate in January 2012 was 7.7%. By 2015, the employment rate in the 20–64 age group had increased to 72% and was expected to rise to 76% by 2020 (see Notes on National Reform Programme, 'Estonia 2020'). Figure 7 shows the macroeconomic developments over the study period, 2000–2015 in GDP growth rate.

Figure 7. Macroeconomic development - Estonia, 2000-2015. Source: Composed by author based on WBI data.



The Global Competitiveness Index (GCI) did not feature Estonia in its 2000 report. The GCI is defined by the World Economic Forum (WEF). It is defined based on a set of institutions, policies, and factors that determine the level of productivity in a country, conditions of public institutions and technical conditions (WEF, GCI, 2013). By 2004, Estonia had taken 20th place and by 2010, 35th place. It moved up a few notches to 30th place by 2015. Globally, Estonia was well placed on the GCI. The countries in the EU region generally saw a marked increase in GDP over the period under review. The European regional GDP is shown in Figure 8.

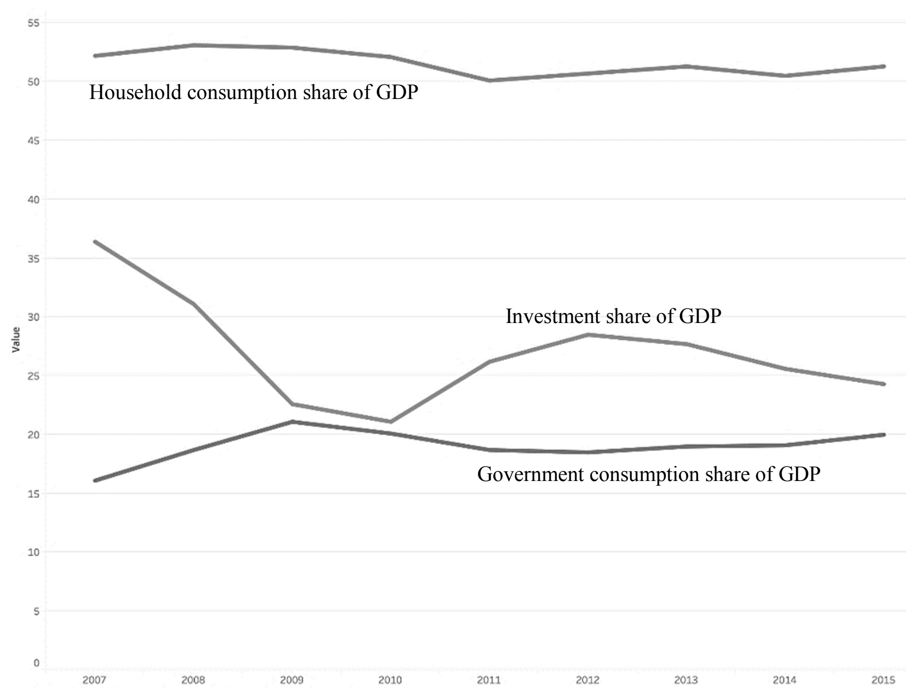
Figure 8. Regional GDP, 2000-2012. Source: Composed by the author based on Eurostat data.



4.2.1. Household consumption as a share of GDP

Household spending is the amount of final consumption expenditure made by resident households to meet their everyday needs, such as food, clothing, housing (rent), energy, transport, durable goods (notably cars), health costs, leisure, and miscellaneous services, according to the OECD and Eurostat. It is typically around 60% of GDP and is therefore an essential variable for economic analysis of demand. In addition to household consumption from the demand side, government consumption, investment consumption and net trade are all demand side consumption expenditure accounting for GDP growth. Figure 9 shows the consumption share of GDP for the government of Estonia, households, and investment share of GDP between 2007 and 2015. It must be noted that no data were available for 2000–2006 from the OECD database at the time of retrieval. Government expenditure dipped in 2009 but remained steady afterwards between 20 and 30 per cent of GDP. The challenge in analysing business investment is that as a measure it only gives a partial story because it takes no account of the quality of the business investment (its contribution to growth) or of intangible investment which is often larger than physical investment. The service-based economy often invests relatively more in intangibles than other areas of the economy.

Figure 9. Consumption and investment in Estonia, 2007-2015. Source: Composed by the author based on Eurostat data.



4.2.2. Estonia's sector shares in total GDP

In the innovation- and technology- led economic growth model (see section 2.3) that promotes economic growth, the tertiary sector should have continued to increase in its relative size and should account for more than 50 per cent of GDP. In most advanced economies (e.g., the United Kingdom), there has been a broad-based shift in the structure of their economy from manufacturing to services (particularly, knowledge-based services). As shown in Figure 10, Estonia's secondary sector share of total GDP has remained the largest chunk since 1995, and therefore also from 2000 through to 2015. Obviously, mining, agriculture and other primary activities are constantly giving way to the secondary (manufacturing) sector and the tertiary (services) sector. To arrive at a technologically accomplished state, the service sector share must increase further. Sectoral shares in the growth model are on the supply side of economic analyses in this sense. Figure 10 shows Estonia's distribution of sector shares in total GDP by values.

Figure 10. Sector shares in total GDP, 2000 - 2015. Source: Composed by the author based on Eurostat data.

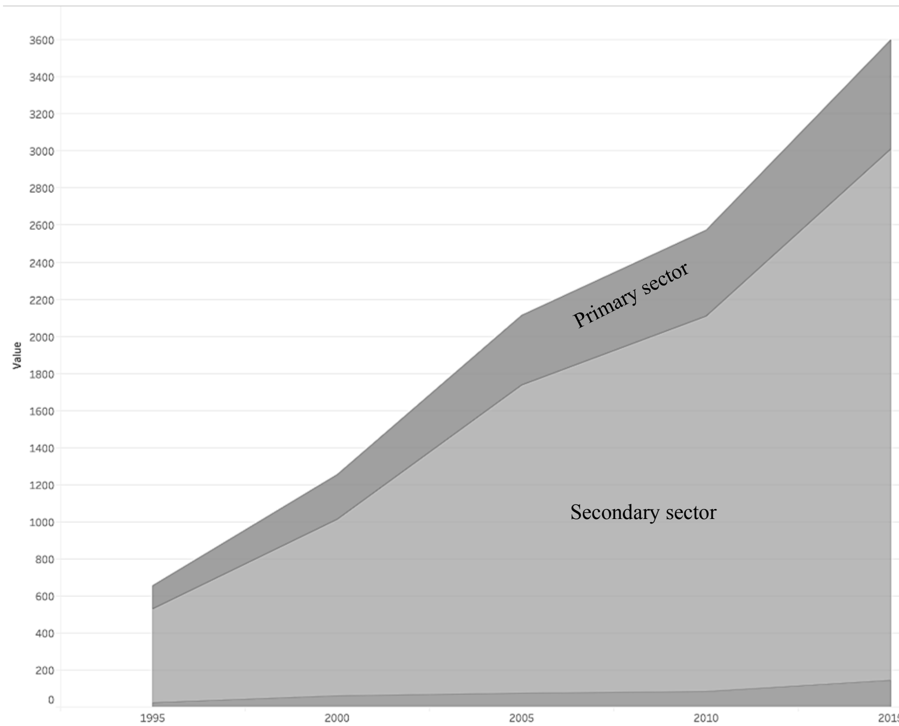
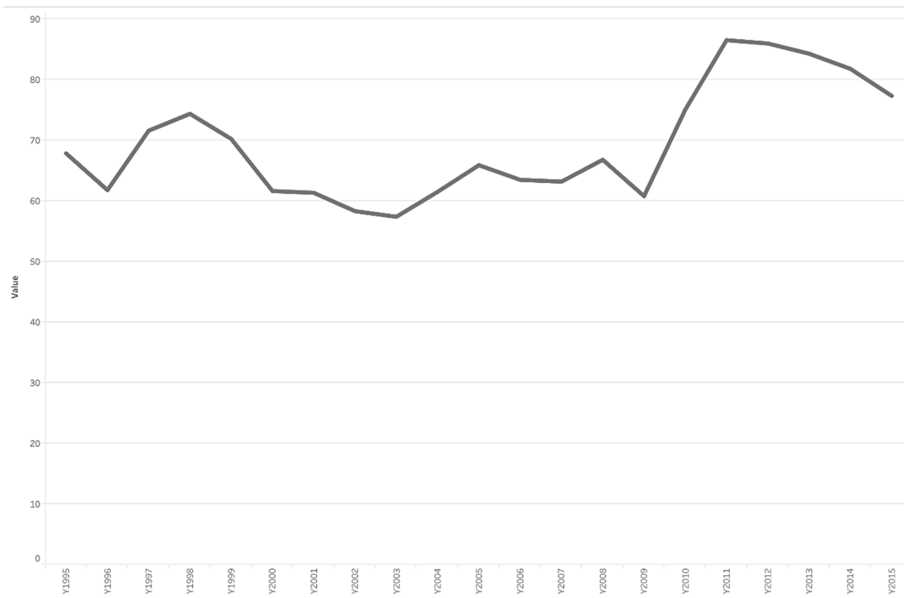
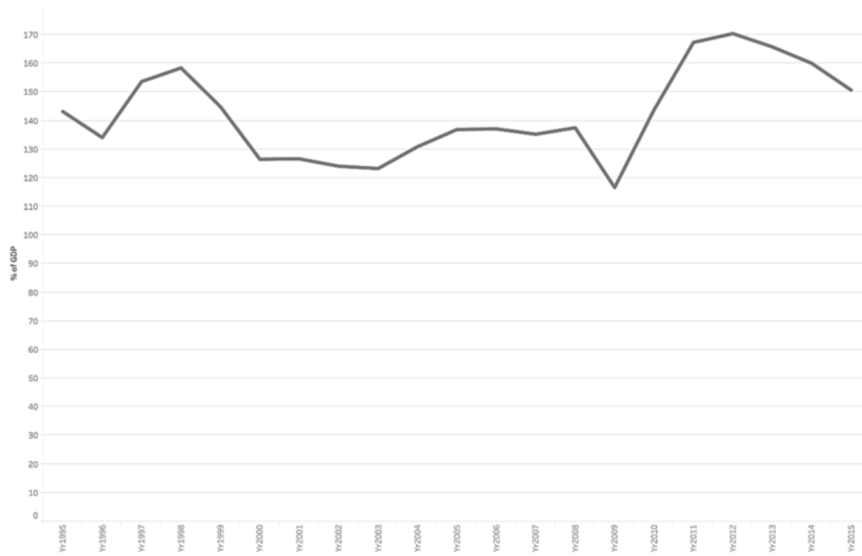


Figure 11. Estonia's export share in GDP, 1992-2015. Source: Composed by the author based on Eurostat data.



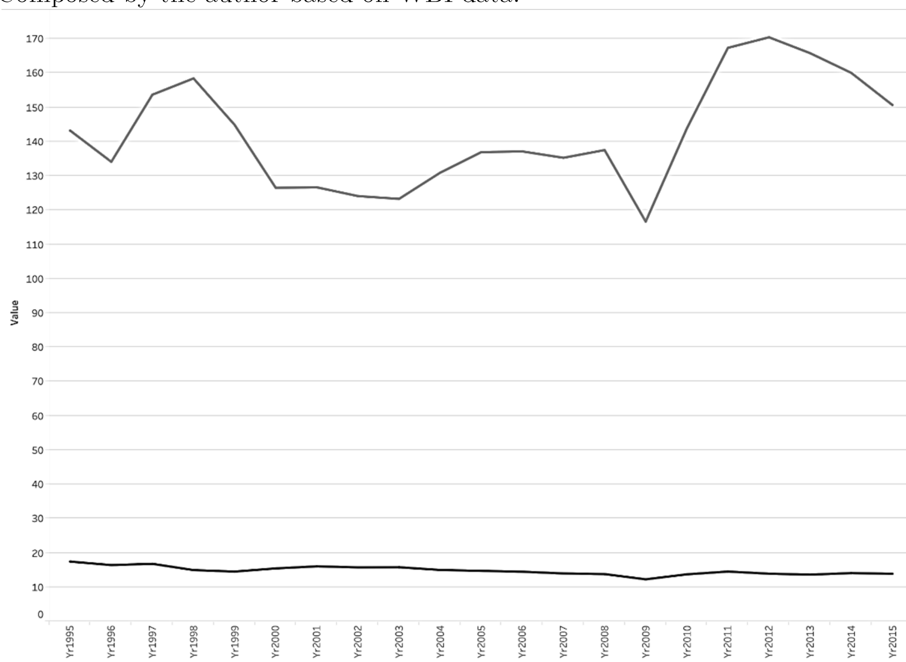
The share of exports remained quite steady before and after 2000 and started increasing after 2009, taking a nose-dive in 2012. Figure 11 shows the export share (as %) in GDP between 2000 and 2015. The World Bank defines exports of goods and services as the value of all goods and other market services provided to the rest of the world by a nation. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments. WBI (2019).

Figure 12. Share of Estonia’s trade surpluses in GDP, 1995 - 2015. Composed by the author based on WBI data.



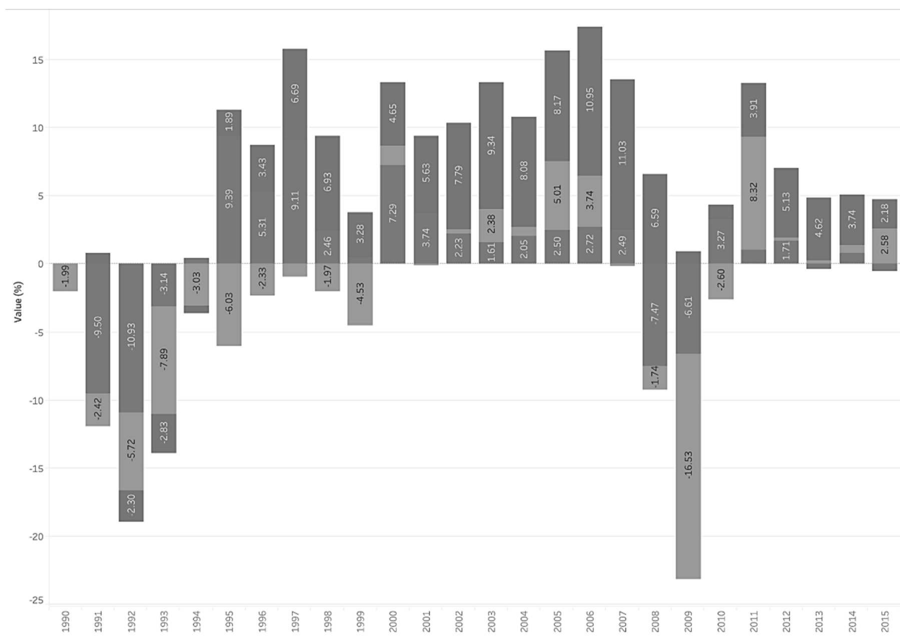
In the formula for GDP, the balance of trade is known to be a key component. GDP is known to increase when there is a trade surplus: where the total value of goods and services that domestic producers sell abroad exceeds the total value of foreign goods and services that domestic consumers buy. The share of Estonia’s trade surpluses in GDP between 2000 and 2015 has remained relatively stable (see Figure 12).

Figure 13. Share of Estonia's GDP and trade in global totals, 2000 - 2015. Composed by the author based on WBI data.



One of the characteristics of the more recent economic growth models includes the increase in the degree of globalization in an economy, which has an impact on economic innovation. This pertains to country-level economic development comparisons in relation to other countries on various indicators (Caselli, 2013). This is an indicator of the relative importance of international trade in the Estonian economy – as one of the measured indicators of globalization – calculated by dividing the aggregate value of imports and exports over a period by the GDP for the same period. Estonia's share of trade in global totals (see Figure 13) show an equally steady movement over the period between 2000 and 2015.

Figure 14. Decomposition of Estonia's GDP growth, 2000 - 2015. Source: Composed by the author based on The Conference Board (2019) data.



Growth is calculated as log-difference. Stacked bars show capital growth, labor growth and TFP growth

The Conference Board is a global, independent business membership and research association formed in 1916. The Board provides the world's leading organizations with the practical knowledge they need to improve their performance and better serve society. The Board defines Total Factor Productivity (TFP) growth as an account for the changes in output not caused by changes in labour and capital inputs. TFP growth represents the effect of technological change, efficiency improvements, and our inability to measure the contribution of all other inputs (Conference Board, 2018).

In Figure 14, data from the Conference Board covering the period 2000–2015 for Estonia shows a decrease in total factor productivity up to 2008, then a steep descent in 2009, recovering in 2010. This may be explained by the effects of the world economic crisis of 2008. The decline in the labour force in recent years and the lower rate of urbanization may also have contributed to a higher capital/labour ratio and lower capital productivity growth in Estonia. These factors and more make a stronger case for Estonia to find new ways to boost productivity.

In sum, Estonia's population did not change between 2000 and 2015 (see Section 4.1). There are signals that the economic transformation in Estonia during the period was anchored in growth drivers such as the shift in the economic growth model towards consumption, services and higher value-added manufacturing and innovation. This is reflected in the increase in the tertiary sector activities as a share in total GDP in Estonia, exports, trade and good economic growth rates between 2000 and 2015. Estonia's growth model does not only suggest country-level development, but at levels that are competitive both regionally and globally. The more significant question is what the sources of these economic developments have been over the study period. There are several potential factors, some of which are analysed in the following sections.

4.3. Establishing the relationship between R&D expenditure, number of patent applications and economic growth - Estonia only

This section of the work estimates the causality relationship between R&D expenditures, number of patent applications (independent variables) and economic growth (dependent variable) for Estonia. But first, the variable description and data sources (see Table 4). This is followed by the tested hypotheses and assumptions:

Table 4. Variable description and data sources. Source: Composed by the author.

Variable	Description	Data Source
GDPPC	GDP per capita (constant 2010 USD)	World Development Indicators
Research and Development (R&D) Expenditure	Research and development expenditure (% of GDP)	World Development Indicators
Patent Applications (PA)	Total Patent Applications (residence and non-residence)	World Development Indicators

The tests were run in SPSS version 26.

- **H_1**: R&D expenditure and number of patent applications are positively associated with the economic growth of Estonia.
- **Null Hypothesis**: R&D expenditure and number of patent applications have no significant role in predicting the economic growth of Estonia.

A **Pearson Correlation Test** was undertaken to check the following assumptions:

1. **Assumption 1**: That the samples consist of related pairs.
2. **Assumption 2:** Independent and dependent variables are continuous and linearly related.
3. **Assumption 3:** The variables follow a bivariate normal distribution.
4. **Assumption 4:** Homogeneity of variances (that is the variance of one variable is stable at all levels of the other variable).

5. **Assumption 5:** That there are no outliers.

Table 5 shows the descriptive statistics in relation to the tests for Estonia. Figure 15 shows the Pearson correlation chart. Table 6 shows the results of the tests for heteroskedasticity.

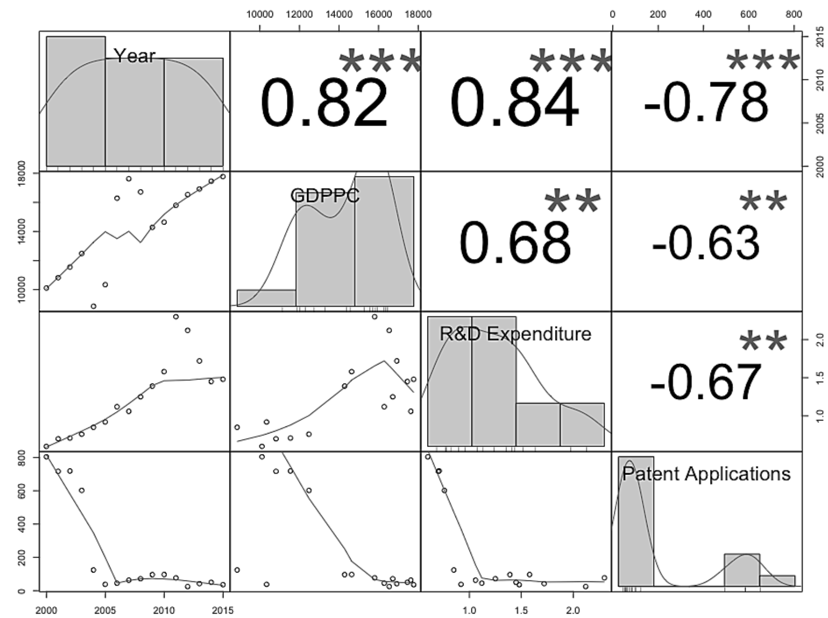
Table 5. Descriptive statistics (2000-2015) - Estonia. Source: Composed by the author.

	Min	**Max**	**Mean**	**Std. Deviation**
GDPPC	8850	17773	14260.44	3088.14
R&D*	1	2	1.25	.509
Patents (PA)	25	804	225.44	292.74

*R&D values are expressed as % of GDP

As can be seen from Figure 15, the variables have a linear relationship and are positively correlated. A strong relationship exists between the variables. In addition, the level of significance at 95% confidence interval shows that the correlations are statistically significant.

Figure 15. Pearson correlation chart. Source: Composed by the author.



t = 3.4245, df = 14, p-value = 0.004108
alternative hypothesis: true correlation is not equal to 0
**. Correlation is significant at the 0.01 level (2-tailed).

Table 6. Test for heteroskedasticity. Source: Composed by the author.

Tests for Heteroskedasticity				
	Chi-Square	df	Sig.	
Modified Breusch-Pagan Test for Heteroskedasticity [a,b,c]	2.208	1	.137	a. Dependent variable: gdppc b. Tests the null hypothesis that the variance of the errors does not depend on the values of the independent variables c. Predicted values from design: Intercept + rnd + pa + year
Breusch-Pagan Test for Heteroskedasticity [a,b,c]	7.384	1	.007	a. Dependent variable: gdppc b. Tests the null hypothesis that the variance of the errors does not depend on the values of the independent variables c. Predicted values from design: Intercept + rnd + pa + year

4.3.1. Regression results - Estonia

Table 7. Regression results - Estonia. Source: Composed by the author.

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.717[a]	.514	.439	2312.896

[a]Predictors: (Constant), pa, rnd; [b]Dependent Variable: gdppc

From Table 7, the R value 0.71 indicates that a strong relationship exists between the number of patent applications, R&D

expenditure, and GDP per capita. This implies that if the number of patent applications and R&D expenditure variables of a country are good, there is a strong likelihood that GDP per capita will be good.

The adjusted R-squared value 0.439 indicates that about 43.9% of the variation in GDP per capita can be explained by the variation in the variables – R&D expenditure and number of patent applications.

Table 8. ANOVA table - Estonia. Source: Composed by the author.

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	73506433.556	2	36753216.778	6.870	.009[b]
	Residual	69543352.382	13	5349488.645		
	Total	143049785.938	15			

[a]Dependent Variable: gdppc; [b]Predictors: (Constant), pa, rnd

The ANOVA results (see Table 8) show how well the equation fits the data and predicts the dependent variable. A significance value of 0.009 means the regression model predicts the dependent variable significantly well, indicating the statistical significance of the regression model.

Table 9. Coefficients table - Estonia. Source: Composed by author.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11557.062	2504.520		4.614	.000
	R&D	2778.817	1581.624	.458	1.757	.102
	PA	-3.424	2.748	-.325	-1.246	.235

[a]Dependent Variable: gdppc;

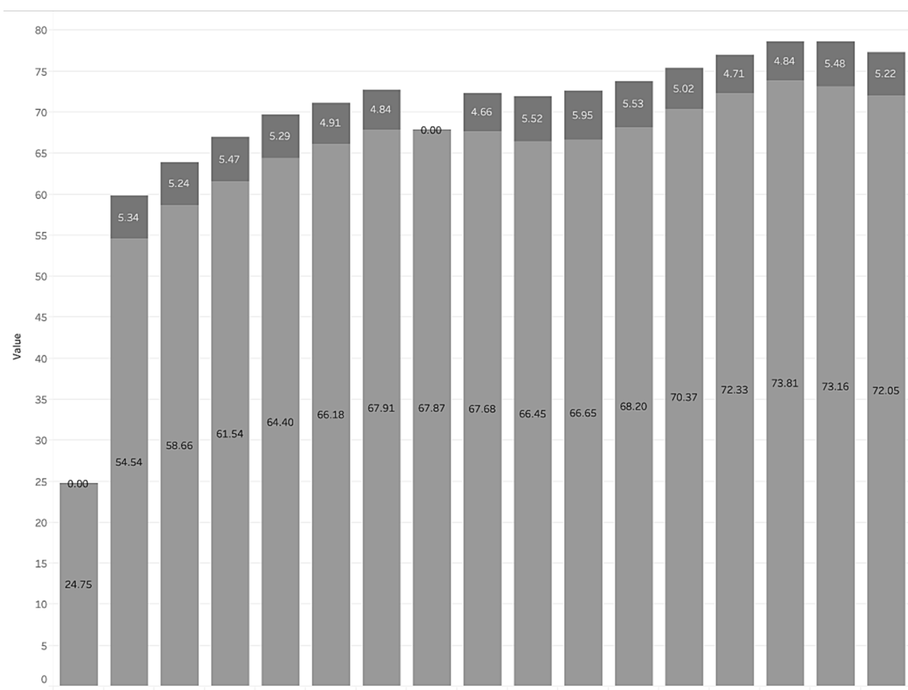
Based on the above statistics, the relationship between the variables can be predicted. Table 9 reports that the R&D variable (significance value = 0.102: $p>0.05$) and patent variable (significance value = 0.235: $p>0.05$) are not significant predictors of GDP per capita in Estonia for 2000 and 2015. Therefore, the Null Hypothesis is accepted and research hypothesis H_1 is rejected. **R&D expenditure and Number of Patent Applications do not have a significant role in predicting GDP per capita in Estonia**.

In this section, as hypothesized, an estimation of the causality relationship between R&D expenditures, number of patent applications (as input variables) and economic growth (GDP per capita as a dependent variable) was performed. The Null hypothesis was confirmed, suggesting that among the growth factors contributing to Estonia's economic development between 2000 and 2015, R&D expenditure and number of patent applications may be insignificant.

4.4. Human capital development

In this section, the role of human capital development in driving economic growth and development (see H_2 in section 3.5) will be analysed. According to Thirwall and Pechaco-Lopez (2017:210), there may be a close association between education and the mainsprings of technological progress. Improvements in education and skills can considerably increase the productivity and earnings of labour. But the capacity to absorb and use physical capital may be limited by, among other things, investment in human capital. Figure 16 shows the gross enrolment in tertiary education and government expenditure on education (% of GDP) for Estonia.

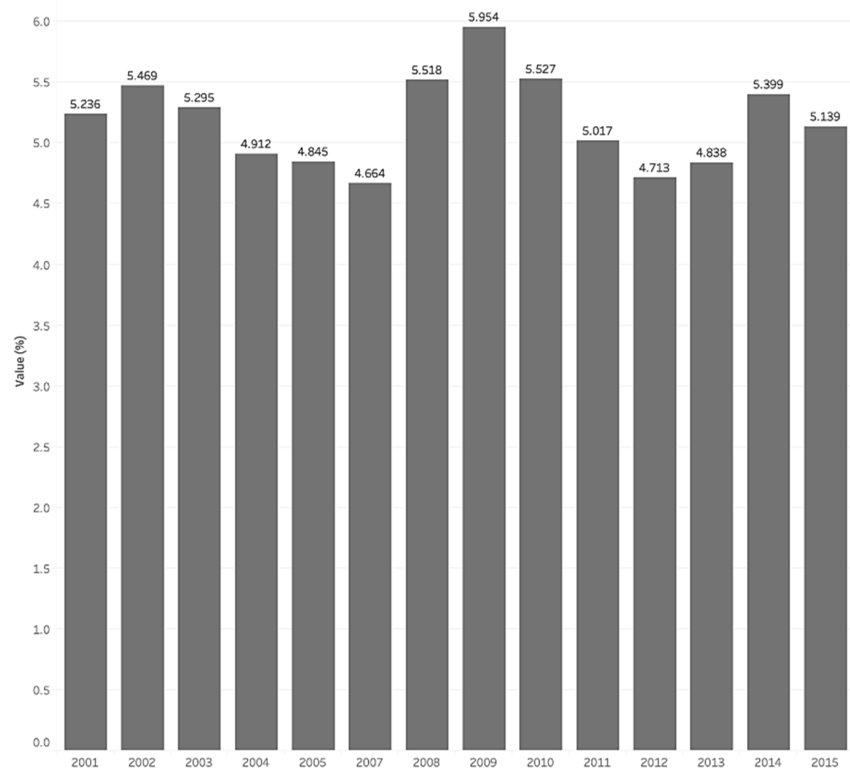
Figure 16. Gross enrolment ratio, tertiary and government expenditure on education. Source: Composed by the author based on WBI data.



Estonia recorded strong performance on the Human Development Index (HDI) in 2000 with a score of 0.781. Between 2000 and 2010, the average annual HDI growth in percentage terms was 0.70. This remained stable between 2010 and 2015 at 0.65. It must be noted that Estonia, from about 1991, had recorded an HDI of 0.726, a marginal increase in 2000. Estonia's human development capabilities continues to hit above EU average levels. Consistently over the study period, ranging between 0.781 in 2000, 0.838 in 2010 and 0.865 by 2015. The analysis of human development growth in Estonia is appended to this work (see Appendix 4).

Figure 17 also shows Estonia's share of total education expenditure in GDP between 2000 and 2015, indicating investment in education. No data is available for 2006; therefore, this is excluded. The most expenditure on education was made by the Estonian government in 2009 (5.95% of GDP), the least in 2007 (4.66% of GDP).

Figure 17. Share of total government education expenditure in GDP, 2000-2015- Estonia. Source: Composed by the author based on OECD data.



In this section, the hypothesis that human capital development would have a significant influence on Estonia's economic developments over the study period was put to the test using descriptive data. The data, especially that reflected in the HDI provides strong signals that human capital development has remained steady in the case of Estonia, even prior to 2000. Human capital affects economic growth by helping to develop the knowledge and skills of the people in a given country, which is a prerequisite for R&D activities to thrive. In this sense, the quality of work is also improved through increased investment in education. The evidence in the case of Estonia shows strong signals of human capital development in relation to economic growth. It is noteworthy that Estonia's domestic spending on R&D activities (as a % of GDP) is substantially less than 3%. Meanwhile in the European Council Conclusions in 2010, the strategy set towards the improvement of conditions for R&D is 3% of GDP (see section 2.6.2).

4.5. Technological innovation

In this section, internet usage and broadband internet access in Estonia are analysed (see H_2 in section 3.5) to establish whether the evidence submitted is sufficient or necessary, in the sense of Beach and Pedersen's (2003) matrix, and whether to place reliance on this in making inferences toward answering RQ2.

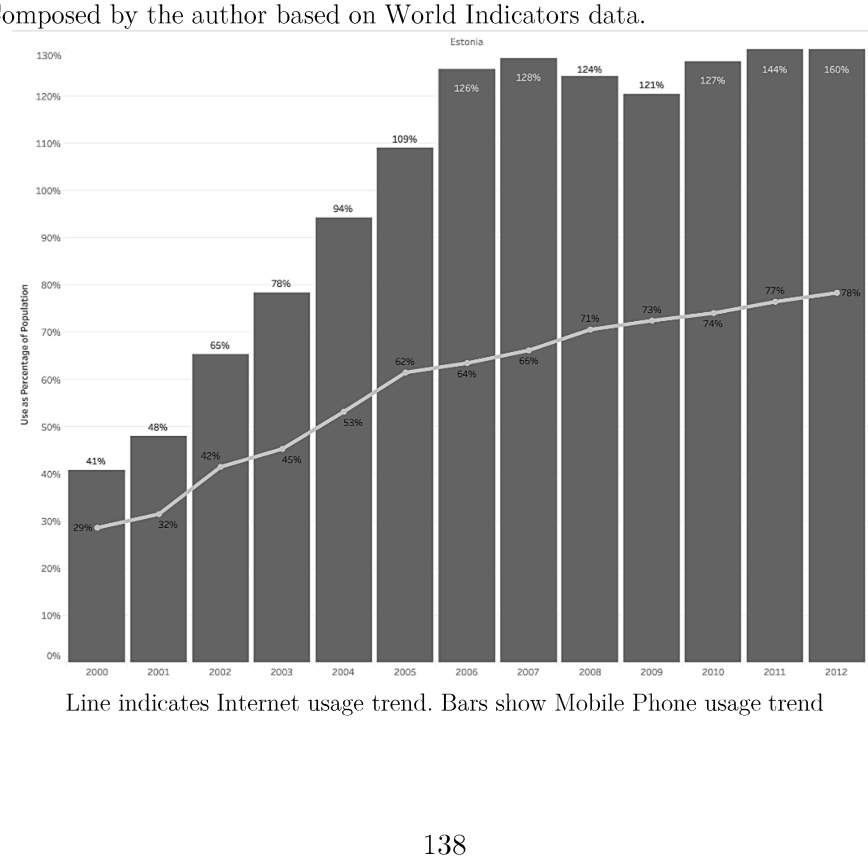
4.5.1. Internet usage in Estonia

Data available from the databases of the UN and World Indicators clearly showed the state of internet usage per 100 people in Estonia (14.5% as at 1999) before 2000. Internet usage picked up steadily rising from 28.6% in 2000 to 61.5% in 2005 (percentage change of 32.9). By 2010, 74.1% of internet users had been recorded (thus, a percentage change of 13.21 since the 2010 numbers), jumping to 84.2% by 2014 (a percentage change of 10.1). Conversely, the number of individuals who had never used a computer before dropped from over 32% in 2006 to a little over 20% in 2010 and significantly, to less than 10% by 2015.

By 2015, 64% of Estonian internet users ordered some product or service from the internet and slightly more than a third (37%) made a financial transaction of some kind on the internet. Eighty-seven per cent (87%) of 16–74-year-old internet users in Estonia used public sector services and information, sharing second place with Finland among the EU member states. By 2016, 87% of 16–74-year-old Estonian residents used the internet in the 1st quarter of 2016, surpassing the EU average by 5 percentage points – 85% of 16–74-year-olds used the internet daily (the EU average stood at 79%). In the 16–34 age group, almost everyone used the internet. Of the 16–24-year-old internet users, 91% used the internet on a mobile phone while on the move (see Figure 18).

By 2000, per every 100 inhabitants, penetration of main telephone lines was 38%. This dropped to 33.5% by 2005 and thence up again to 37.4% by 2010. By 2013, it was hovering around 33%. By 2004, the percentage of households with broadband internet connection was about 20%. By 2015, this had risen to almost 90% of households with broadband internet connection. Between 2005 and 2011, some households still had modems or Integrated Services Digital Network (ISDN) connections which were non-existent by 2012 to 2015 (see Figure 18).

Figure 18. Internet and mobile phone usage per capita, 2000-2012. Source: Composed by the author based on World Indicators data.



Line indicates Internet usage trend. Bars show Mobile Phone usage trend

4.5.2. Broadband access in Estonia

Broadband access in enterprises in Estonia rose marginally from over 60% in 2004, to about 90% by 2010 and almost 100% coverage by 2015. By 2016, more than a fifth (22%) of Estonian enterprises used paid cloud services especially e-mail and file storage services on the internet, and financial and accounting software applications. Data from the Statistics Estonia database reveals as at end of 2015 that 29% of Estonian enterprises had vast experience in big data analysis of information and communications, 28% in water supply and waste management, and 21% in financial and insurance data analysis. Further, more than three quarters (78%) of Estonian enterprises had their own website and 37% of enterprises used social networking services such as Facebook and LinkedIn. Seventy-seven per cent (77%) of Estonian enterprises gave their employees remote access to the enterprise's mailing system, documents, or applications.

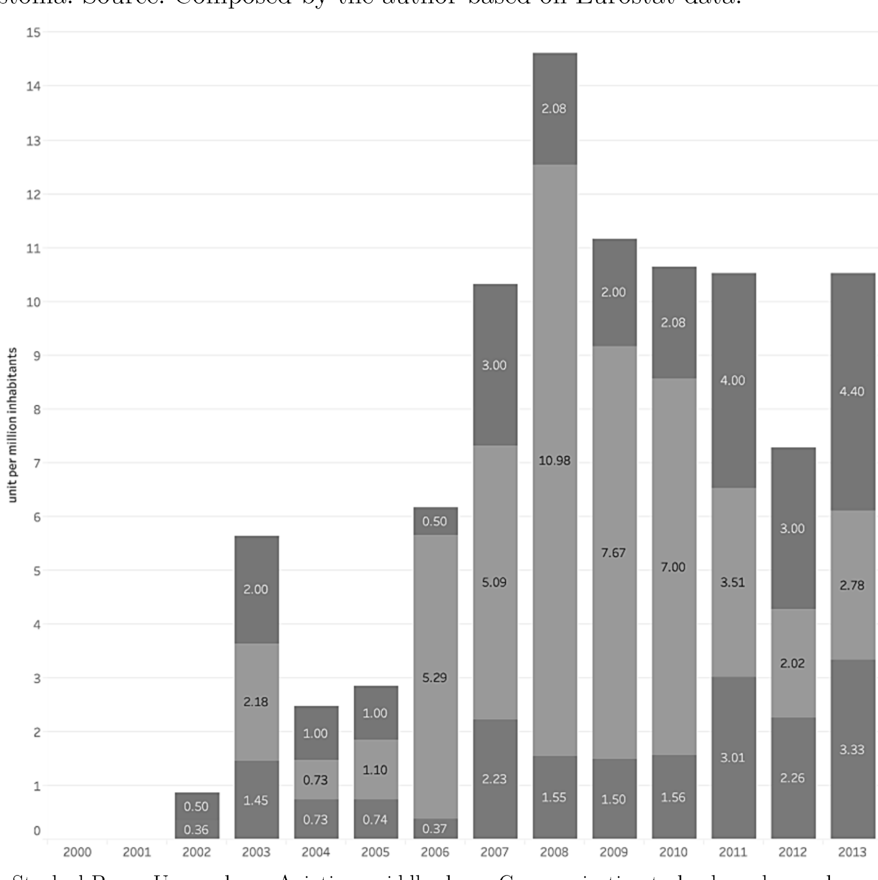
The networked readiness framework of the World Economic Forum translates into the networked readiness index (NRI), a composite indicator made up of indexes and sub-indexes, that measure each country's ability to leverage ICTs for national development. The NRI report series commenced in 2001. By 2002, Estonia ranked 23rd. In 2004, Estonia's ranking dropped a notch to 24th and then one more notch in 2004. Estonia is quoted as 'the leader amongst the Eastern European countries with a rank of 25' (The NRI 2003–2004, Chapter 1, pg. 4). By 2005, Estonia redeemed its 23rd place again. The best-known rankings in the history of the country were recorded in 2007 and 2009, when Estonia ranked 18th place. In 2008, Estonia took 20th position in the world. In 2010 and 2011, Estonia ranked 25th and 26th respectively, dropping to 24th in 2012, 22nd in 2013 and 21st in 2014. By 2015, Estonia ranked 22 among 148 countries globally. The analysis reflects this positive trend in networked readiness for Estonia. A detailed NRI analysis for the period 2012 to 2015 is appended to this work. Due to changes to the NRI structure between 2001 and 2011, that data was not compared (see Appendix 5).

In the Baltic region, Vengerfeldt et al. (2004) have discussed the rapid pace of Estonian ICT development in parallel with information policy processes from the late 1990s. Their conclusions have indicated that between 1997 and 1999, Estonia took off, leaving behind the other Baltic countries of Latvia and Lithuania. The Lisbon review of the competitiveness of EU member states listed Estonia in 12th place (the highest of the ten member states that joined the EU in 2004), Lithuania was in 20th position, rising from 21st position, while Latvia was in 22nd position having fallen from 16th position in 2004 (World Economic Forum, 2006). Vengerfeldt (op cit.) also noted that among the three Baltic countries, Estonia has superior technical infrastructure; more of its citizenry interact with the government and state agencies via the internet and the internet is generally well integrated into the personal lives of Estonians.

Number of patent applications, as argued earlier in section 4.3, is an important indicator of technological innovation. Technological innovation is measured globally, such as on the NRI, where Estonia is shown to have excelled over the study period, based on placement so far. Such efforts as shown above support technological developments while enabling continuous learning. The goal has been to expand the technological frontiers of Estonia, which is eventually reflected in technological developments and their impact on economic growth. Private entrepreneurship plays an important role in this context, in that, enhancing competition and improving productive use of resources can be supported. Figure 19 shows high tech patent applications to the European Patent Office (EPO) from

Estonia for the period 2000–2013. At the time of retrieving the data from the EPO web portal, there was no record available for the years 2014 and 2015. Patent applications to the EPO from Estonia were for aviation, communication technology and computer and automated business equipment (see also section 2.5.2).

Figure 19. High tech patent applications to the EPO by type, 2000-2013- Estonia. Source: Composed by the author based on Eurostat data.



Stacked Bars - Upper shows Aviation, middle shows Communication technology, lower shows Computer and automated business equipment

In concluding this section, technological innovation has been intimately linked to R&D activities and economic growth by Türedi (2016), including its link to patents (see subsection 2.5.2). Together with human capital development (see section 4.4), a descriptive case study method was used to test the hypothesis that technological innovation has a significant impact on economic growth in this section. The analysis has provided support for the hypothesis. Estonia has ranked relatively well on global innovation performance indicators. Mobile phone penetration as well as broadband access in households and businesses increased tremendously over the study period. So also did internet usage, which creates the needed leverage to harness a knowledge-based economy and increase Estonia's performance in technological innovation, as submitted in the section.

4.6. Regional innovation capability

In this section and the following, section 4.7, puts the convergence hypothesis to the test using **smoking gun tests** (see section 3.4). The results of the panel data analysis are presented. Meanwhile, the results of the spatial data analysis are submitted in section 4.7. The purpose of the analyses is to show that networked co-operation in the EU regional innovation system resulted in innovativeness at regional level, regional innovation policy applications and economic growth, eventually promoting the convergence of EU regional economic development (see section 2.4.5). Economic convergence has been measured in several ways. The World Bank (2015), for example, considers narrowing income level differences among countries in a region, innovation capacity due to the common application of policies, the globalization of ideas, knowledge, access to information and harmonization of living standards across a region as economic convergence. In this work, the World Bank definition of economic convergence resulting from regional innovation capability is implied in the analysis. **H_3** is re-stated:

- **H_3**: Regional innovation capability has a significant positive effect on regional economic growth.

Panel data analysis is used as the method in this section. According to Baltagi (2001), panel data analysis allows more variability than cross-sectional or time series data analysis alone, which was affirmed by Arbia et al. (2002, 2003, 2011), Baumont et al. (2002), Peracchi and Meliciani (2003), Kennedy (2008:282), Hsiao (2005) and other scholars. The panel data regression analysis in this work is performed in the following ways.

- Pooled ordinary least squares (OLS) model estimation
- Fixed effects model estimation
- Random effects model estimation
- Generalized method of moments (GMM) estimation

The choice of panel data analyses was intended to increase the number of observations and be able to control for individual unobserved heterogeneity (differences) as suggested by Baltagi and Levine (1986). While the pooled OLS is just like any linear model estimation, the fixed and random effects models are both examples of heterogenous panel data models. Generally, panel data models examine the effects of groups (individual-specific) or time-specific effects, or both, in order to deal with the heterogeneity that may or may not be observed in the data. These effects are either fixed or random (Park, 2011).

To control for heterogeneity in the panel data analysis in this work, it is assumed that the selected EU countries are heterogenous and that there may be other factors (time or country-invariant) which could impact on regional economic growth and development, aside from the input variables in this study. The selected EU countries are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden and the United Kingdom. The period of the analysis, 2000–2015, was chosen to maximise the number of observations, given the data availability. Since some of the data is not available, the panel is unbalanced, and the number of observations depends on the input variables.

Aigner, Hsiao, Kapteyn and Wansbeek (1984) among other scholars have warned that the use of panel data estimation models can introduce a set of problems, including distortions in measurements and selectivity problems, when spatial dependency is not accounted for. In the fixed effects estimator, estimates are not biased by any omitted variables, which are constant over time. The main measurement errors in panel data estimation models are a result of ignoring between-country variations and a reduction in bias, which implies higher standard errors as suggested by Durlauf et al. (2005). The GMM estimator developed by Arellano and Bond (1991) is suggested to eliminate these possible measurement errors in panel data model estimations. The GMM is analogous to maximum likelihood (ML). However, the GMM uses assumptions about specific moments of the independent variables instead of assumptions about the entire data distribution, which has been argued to make the GMM more robust than ML, for example. An important advantage of the GMM estimator is that it minimalizes the risk of the non-stationarity of series.

Prior to submitting the results of the analysis, the variables are described, and the data sources are provided in Table 10.

Table 10. Variable description and data sources - panel data analyses. Source: Composed by the author.

Variable	Description	Data Source
GDPPC	GDP per capita (constant 2010 USD)	World Development Indicators
R&D Expenditure (R&D)	Research and development expenditure (% of GDP)	World Development Indicators
Number of Patent Applications (PA)	Total Patent Applications (residence and non-residence)	World Development Indicators

4.6.1. Panel data results for 26 EU countries

Using Panel data, this section of the work estimates the causality relationship between the independent variables – R&D expenditure and the number of patent applications – and the dependent variable – economic growth for the selected EU countries, 26 in all. The model is developed based on the Holz-Eakin, Newey, and Rosen (1988) model.

In equation (1), the representation is a homogenous model. The constant α is the same across groups and time. The convergence coefficient β is constant across groups and time and the unobserved country-specific differences across the group enter the model only through the error term ε_{it}.

$$GDPPC_{it} = \alpha + \beta_1 R\&D_{it} + \beta_2 PA_{it} + \varepsilon_{it} \qquad (1)$$

Where

$GDPPC$ and $R\&D, PA$ - are the variables between which a relationship is investigated

$GDPPC_{it}$ - refers to the per capita GDP of EU country i in year t

$R\&D_{it}$ and PA_{it} - refer to R&D expenditure and number of patent applications of EU country i in year t

β is the convergence coefficient

α is the constant term (fixed effects) in the model, and

ε_{it} is the error term.

In the first step in the panel data analysis, a Pooled OLS model is estimated. In this, the panel is treated as one large pooled dataset. The model parameters β and α are directly estimated using the Pooled OLS. In this Pooled OLS model, the dataset is treated as cross-sectional data and it is ignored that the data has time and individual dimensions, fixing all other "random" unobserved variables as constant. For this, the assumptions are similar to the ordinary linear regression and checked for a relationship between the independent variables and dependent variable.

Table 11 shows the results of the pooling model test. The pooling data assumes that two or more independent sets of data are of the same type. Pooled data occur when we have a time series of cross sections yet the observations in each cross section do not necessarily refer to the same unit.

Table 11. Pooling model statistics. Source: Composed by the author.

*Unbalanced Panel: n = 26, T = 14-16, N = 413				
Model = Pooling				
Residuals:				
Min	**1Q**	**Median**	**3Q**	**Max**
-29073.0	-10189.0	-3014.0	6357.6	77838.0
Coefficients:				
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	1.0443e+04	1.6513e+03	6.3238	6.678e-10 ***
R&D	1.4930e+04	1.0983e+03	13.5938	< 2.2e-16 ***
PA	-9.5470e-02	7.0423e-02	-1.3557	0.176
Total Sum of Squares: 1.7371e+11				
Residual Sum of Squares: 1.1689e+11				
R-Squared: 0.3271				
Adj. R-Squared: 0.32382				
F-statistic: 99.6506 on 2 and 410 DF, p-value: < 2.22e-16				

Signif. codes: 0 `***` 0.001 `**` 0.01 `*` 0.05 `.` 0.01 ` ` 1

*There are random missing observations in the dataset, so fewer time periods (T).

It can be inferred from the results of the Pooling model, which sought to test the hypothesis that each coefficient is different from 0, and to reject this, the p-value has to be lower than 0.05 (95%), that the R&D variable has a significant influence on the dependent variable, GDP per capita, for the EU economic region. To check the model fit, if the overall p-value is less than 0.05, then the model is good. Using the F-test result to see whether all the coefficients in the model are different to zero, it can be concluded that it is greater than 0.05, therefore the Pooling model is rejected.

Regional innovation capacity depends on the potential to produce a series of innovation products, and among them the most important factor is R&D expenditure (Furman et al. 2002). Such innovation activities are associated with the number of patent applications. The results of the Pooled model test suggest that other unobserved factors, including country and time-specific characteristics (differences in innovation capacity) could impact economic growth in the region, which were ignored in this model. The fixed effects model takes care of this omission by considering those individual differences not reflected or controlled for in the OLS Pooled model. The omissions in the fixed effects model are subsequently also catered for in the random effects model to now consider individual country variations (differences) in innovation capacity as well as time-dependent variations.

First, the fixed effects in equation (1) need to be eliminated in case they lead to erroneous estimation results. For that reason, these fixed effects are eliminated by taking the difference of equation (2).

$$GDPPC_{it} = \alpha_i + \beta_1 R\&D_{it} + \beta_2 PA_{it} + \varepsilon_{it} \qquad (2)$$

α_i is the constant term (the fixed effects from whatever other variables are unobserved but remain constant in the model), which could affect the outcome of economic growth analysis. The constant term refers to country-specific characteristics in this sense which remain unchanged over the time period of the analysis. These are considered constant across individual countries. Alternatively, some countries in the group may share common coefficients on regressors but have group-specific intercepts, which are captured in the fixed effects model. Therefore, between-group estimations (see Table 12), first-differences estimations (see Table 13) and within-group estimations (see Table 14), are performed due to the bias still observed in accounting for $GDPPC_{it}$ in estimating β using the pooled OLS earlier (see Table 11).

Table 12. One-way (individual) effect Between model. Source: Composed by the author.

Unbalanced Panel: n = 26, T = 14-16, N = 413				
Model = Between				
Observations used in estimation: 26				
Residuals:				
Min	**1Q**	**Median**	**3Q**	**Max**
-18394.4	-10458.4	-4144.3	6791.5	69938.0
Coefficients:				
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	9152.46014	7350.58036	1.2451	0.225620
R&D	16277.06881	4946.69118	3.2905	0.003203 **
PA	-0.13708	0.30738	-0.4460	0.659800
Total Sum of Squares: 1.1436e+10				
Residual Sum of Squares: 7610700000				
R-Squared: 0.33449				
Adj. R-Squared: 0.27662				
F-statistic: 5.78003 on 2 and 23 DF, p-value: 0.0092526				

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

In the Between Model, the R&D variable again has a significant influence on the GDP per capita variable. Here, the overall p-value is lower than the threshold of 0.05, and therefore all coefficients in the Between Model are different to 0. The next model was the test of first difference. The random effects assumption is strong. To get rid of this effect, α_i is wiped out using a differencing transformation, from equation (2) which gives us equation (4):

$$GDPPC_{it-1} = \alpha_i + \beta_1 R\&D_{it-1} + \beta_2 PA_{it-1} + \varepsilon_{it-1} \qquad (3)$$

Subtracting equation (2) from the equation (3) gives:

$$\Delta GDPPC_{it} = \beta_1 \Delta R\&D_{it} + \beta_2 \Delta PA_{it} + \Delta\varepsilon_{it} \qquad (4)$$

Where (Δ) denotes the change from (t-1) to (t). In this sense, country-specific errors are differenced out. Time-specific unobserved heterogeneity is eliminated using the Pooled OLS first-differences estimator. The First Difference Model also shows a p-value that is statistically significant (see Table 13). Conversely, the Within Model (see Table 14) and the Random Effects Model (see Table 15) do not.

Table 13. One-way (individual) effect First-Difference model. Composed by the author.

Unbalanced Panel: n = 26, T = 14-16, N = 413				
Model = First Difference				
Observations used in estimation: 387				
Residuals:				
Min	**1Q**	**Median**	**3Q**	**Max**
-6953.708	-319.290	72.316	419.654	11555.592
Coefficients:				
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	4.3433e+02	6.4321e+01	6.7525	5.39e-11 ***
R&D	-2.1744e+03	5.8430e+02	-3.7214	0.0002277 ***
PA	2.3120e-02	6.3105e-02	0.3664	0.7142842
Total Sum of Squares: 594660000				
Residual Sum of Squares: 573870000				
R-Squared: 0.034959				
Adj. R-Squared: 0.029933				
F-statistic: 6.95526 on 2 and 384 DF, p-value: 0.0010784				

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 14. One-way (individual) effect Within model. Source: Composed by the author.

Unbalanced Panel: n = 26, T = 14-16, N = 413				
Model = Within				
Residuals:				
Min	**1Q**	**Median**	**3Q**	**Max**
-10269.92	-1338.84	173.54	1164.62	15175.24
Coefficients:				
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
R&D	3274.672574	465.598589	7.0333	9.268e-12 ***
PA	-0.247955	0.072816	-3.4052	0.0007307 ***
Total Sum of Squares: 2.079e+09				
Residual Sum of Squares: 1789900000				
R-Squared: 0.13904				
Adj. R-Squared: 0.078661				
F-statistic: 31.0877 on 2 and 385 DF, p-value: 3.0494e-13				

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 15. One-way (individual) effect Random Effect model (Swamy-Arora's transformation). Source: Composed by the author.

Unbalanced Panel: n = 26, T = 14-16, N = 413					
Model = Random					
Effects:					
	Var	**Std. Deviation**	**Share**		
idiosyncratic	4649158	2156	0.015		
individual	306031536	17494	0.985		
theta:					
Min	**1Q**	**Median**	**Mean**	**3Q**	**Max**
0.9671	0.9692	0.9692	0.9691	0.9692	0.9692
Residuals:					
Min	**1Q**	**Median**	**Mean**	**3Q**	**Max**
-7946.6	-1368.9	22.8	-6.3	1185.2	15783.3
Coefficients:					
	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**	
(Intercept)	2.7408e+04	3.5522e+03	7.7159	1.201e-14 ***	
R&D	3.4275e+03	4.6818e+02	7.3208	2.464e-13 ***	
PA	-2.2031e-01	7.1158e-02	-3.0961	0.001961 **	
Total Sum of Squares: 2257800000					
Residual Sum of Squares: 1949600000					
R-Squared: 0.13654					
Adj. R-Squared: 0.13233					
Chisq: 64.8263 on 2 DF, p-value: 8.378e-15					

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The random effects model assumes that individual effects (heterogeneity) is not correlated with any independent variables and then estimates error variance specific to groups (or times). Fixed effects are tested using the F-test, while random effects are examined using the Lagrange multiplier (LM) test (Breusch and Pagan, 1980). If the null hypothesis is not rejected in either test, the pooled OLS regression is favoured. The Hausman specification test (Hausman, 1978) compares a random effects model to its fixed counterpart. If the null hypothesis that the individual effects are uncorrelated with the other independent variable, and it is not rejected, a random effects model is favoured over its fixed counterpart.

To decide between the fixed or random effects, **LM tests and Hausman tests** were conducted – the null hypothesis supposes that the preferred model is random effects versus the alternative hypothesis – and the fixed effects model is preferred, according to Green (2008). The aim of these tests was to check whether the unique errors are correlated with the independent variables, and their null hypothesis is that they are not.

LM Test for Random effects vs. OLS
Lagrange Multiplier Test – (Honda) for unbalanced panels
data: gdppc ~ rnd + pa
normal = 48.964, p-value < 2.2e-16
alternative hypothesis: **significant effects**

LM Test for Fixed effect vs. OLS
F test for individual effects
data: gdppc ~ rnd + pa
F = 990.28, df1 = 25, df2 = 385, p-value < 2.2e-16
alternative hypothesis: **significant effects**

To choose between the two regression models, the Hausman test (correlated random effects test) was run to examine whether the difference between the random effects regression and the fixed effects regression is zero. The results are shown in Table 16. The results show that the p-value is not significant (p-value=0.6995: p>0.05); therefore, **the Null Hypothesis is accepted: the preferred model is random effects.**

Table 16. Correlated random effects --Hausman Test. Source: Composed by the author.

Correlated Random Effects --Hausman Test			
Test Summary	**Chisq Statistic**	**df**	**p-value**
Cross-Section random	0.71466	2	0.6995

alternative hypothesis: one model is inconsistent

Next, the test was performed to establish cross-sectional dependence. According to Baltagi (2005), cross sectional dependence can be a problem in macro panels with long time series. However, not a problem in micro panels with fewer years and larger numbers of cases. The null hypothesis in Pesaran CD tests of independence is that residuals across entities are not correlated. Pesaran CD (cross-sectional dependence) tests are used to test whether the residuals are correlated across entities (in this work, countries) to avoid bias in tests results (also called contemporaneous correlation). Table 17 shows the results of the test for cross-sectional dependence in the panels. The p-value (p=0.6995; p>0.05) shows that there is cross sectional dependence; however, in line with Baltagi's suggestion, this is ignored because the panel is considered a micro panel – data on individual countries over a very short period of time (16-year period) in the sense of Baltagi (2005). A large set of units (N=413) are considered for a relatively short number of periods (T=14-16) (See Tables 11-15).

Table 17. Pesaran CD test for cross-sectional dependence in panels. Source: Composed by the author.

Pesaran CD test for cross-sectional dependence in panels			
Test Summary	z	**df**	**p-value**
Cross-Section random	25.4	2	< 2.2e-16

alternative hypothesis: cross-sectional dependence

Aside from the cross-sectional dependence testing, a z-test and Wald test were also performed. Table 18 shows the z-test statistics, which show how likely the results are of being extreme or not than those observed would have been under the null hypothesis. All the p-values are significant (p<0.001***), suggesting that the data is providing evidence that the variables are needed and are relevant.

Table 18. z test of coefficients. Source: Composed by the author.

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	27408.30397	3592.31593	7.6297	2.353e-14 ***
R&D	3427.49164	442.74615	7.7414	9.830e-15 ***
PA	0.22031	0.05665	-3.8890	0.0001006 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 19. Wald test. Source: Composed by the author.

Model 1: GDPPC ~ R&D + PA Model 2: GDPPC ~ R&D				
	Res. Df	**Df**	**Chisq**	**Pr(>Chisq)**
1	410			
2	411	-1	15.125	0.0001006 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

From Table 19, the statistics of the Wald test (X^2) applied to all the independent variable coefficients are statistically significant only in Model 2, where R&D expenditure is accepted as a dependent variable. **Therefore, a one-way causality relationship can be suggested from R&D expenditure to economic growth (represented by GDP per capita) for the 26 EU countries analysed during the period 2000 and 2015.**

4.6.2. Generalised moments method: panel GMM EGLS (cross-section random effects) test

The economic growth literature supports the superiority of the GMM methodology over pooled OLS and fixed effects models when treating typical econometric problems that arise when dealing with panel data and socio-economic variables, such as the endogeneity of input variables, simultaneity and the unobserved heterogeneity (Hansen, 1982, 2000; Woodridge, 2001 and Davidson and MacKinnon, 1993; Hayashi, 2000; and Greene, 2000) of the sampled countries. The results of the analyses using the GMM: Panel GMM EGLS (cross-section random effects) tests are presented in Tables 20 and 21. This statistical method combines observations in the data with information in population moment conditions to produce estimates of the unknown parameters of the model tested.

Table 20. Generalized moments method test. Source: Composed by the author.

Dependent Variable: GDPPC				
Method: Panel GMM EGLS (Cross-section random effects)				
Date: 10/18/19 Time: 16:08				
Sample: 2000 2015				
Periods included: 16				
Cross-sections included: 26				
Total panel (unbalanced) observations: 413				
2SLS instrument weighting matrix				
Swamy and Arora estimator of component variances				
Instrument specification: C COUNTRY YEAR				
Constant added to instrument list				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
R&D	12057.30	37601.64	0.320659	0.7486
PA	1.829972	24.20018	0.075618	0.9398
Control Variable (C)	4633.513	179990.3	0.025743	0.9795
Effects Specification				
	S.D.	**Rho**		
Cross-section random	53801.73	0.9914		
Idiosyncratic random	5003.043	0.0086		
Weighted Statistics				
R-squared:	-2.356959	Mean dependent var:	718.0146	
Adjusted R-squared:	-2.373334	S.D. dependent var:	2300.716	
S.E. of regression:	4222.718	Sum squared resid:	7.31E+09	

Durbin-Watson stat:	0.402207	J-statistic:	1.02E-26
Instrument rank:	3		
Unweighted Statistics			
R-squared:	0.999576	Mean dependent var:	30582.07
Sum squared resid:	3.47E+11	Durbin-Watson stat:	0.008466

In Table 21, the results of the test for equality of means between the series in the data are presented. The results show that p<0.10. These tests measure each independent variable's potential before the model is created. Each of the tests displays the results of a one-way ANOVA for the independent variable using the grouping variable as the factor. It assumes that subgroups have the same mean; therefore, the variability between the sample means (between these groups) should be the same as the variability within any subgroup (within group). If the significance value is greater than 0.10, the variable probably does not contribute to the model.

Table 21. Test for equality of means between series. Source: Composed by the author.

Test for Equality of Means Between Series			
Sample: 2000 2015			
Included observations: 416			
Method	**df**	**Value**	**Probability**
ANOVA F-test	(4, 2072)	603.2531	0.0000
Welch F-test*	(4, 846.87)	19014319	0.0000
*Test allows for unequal cell variances			
Analysis of Variance			
Source of Variation	**df**	**Sum of Sq.**	**Mean Sq.**
Between	4	2.90E+11	7.25E+10
Within	2072	2.49E+11	1.20E+08
Total	2076	5.39E+11	2.60E+08
Category Statistics			

In analysing the relationship between GDP per capita, R&D expenditure and number of patent applications, the results of the panel data analysis indicate that the estimated coefficients of the covariates are significant for one independent variable but not the other. Further, addressing issues adequately with the panel data, the GMM estimation was employed and the results re-established the findings of the earlier method. The results of the Panel EGLS (Cross-section random effects) are presented in Tables 20 and 21. The model exhibits a good fit. From the panel data analyses, **the**

model estimations show a one-way causality relationship between R&D expenditure and economic growth but not with number of patent applications.

The main take-aways from the empirical tests in section 4.6 are that the results covering R&D expenditure may indicate more complex relationships between R&D expenditure and economic growth (Alvarez-Pelaez and Groth, 2005; Guellec, Van Pottelsberghe de la Potterie 2001; Arundel and Kabla, 1988). As suggested by Durlauf et al. (2005) and Nickell (1981), measurement errors are a typical problem due to ignoring the between-country variations and the reduction in the bias, among other panel data problems. Therefore, spatial estimation methods, including **Moran's I index,** and **spatial regressions** are suggested as solutions to deal with panel data problems in the following section 4.7.

In section 4.6, the test of convergence of per capita GDP across the selected countries in the EU region was conducted. It was hypothesized that a significant correlation of economic growth rates and regional development exists across the selected countries in the EU region (see section 3.5). In the models estimated, the spatial effects were ignored, and restrictions were imposed on the models, where heterogeneity was allowed in the parameters of the process describing GDP growth in the region. **The results suggest that only R&D expenditure may explain the convergence of EU regional development,** and not the number of patent applications.

4.7. Spatial data analyses and regressions

In this section, spatial data analysis and spatial regression results are presented. Spatial analysis in this dissertation is a form of statistical analysis where data which has a geographical or spatial aspect is analysed to render maps and terrestrial estimations.

4.7.1. Moran's I and spatial regression

As noted earlier in this chapter, the choice of panel data analyses was intended to increase the number of observations and be able to control for individual unobserved heterogeneity or differences in the data analysed for the 26 EU countries. In testing the β convergence, (see section 4.6) the spatial effect (Arbia et al., 2002, 2003; Baumont et al. 2002) was not considered.

In this section, two key tests are performed: (1) Moran's I and (2) Spatial Regression. Moran's I is a test for spatial autoregression (Moran, 1950), which examines whether a phenomenon is clustered or not. For this, if the absolute value of Moran's I is close to 1, it indicates that the spatial correlation of regional innovation capability is stronger. Spatial regression on the other hand is a regression that has the ability to predict the value of an outcome variable based on the values of independent variables, while accounting for spatial dependency. The two tests employed in this section are used to investigate the spatial patterns of economic growth in the EU region (specifically, in the 26 selected countries) for 2000 and 2015. These are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden and the United Kingdom.

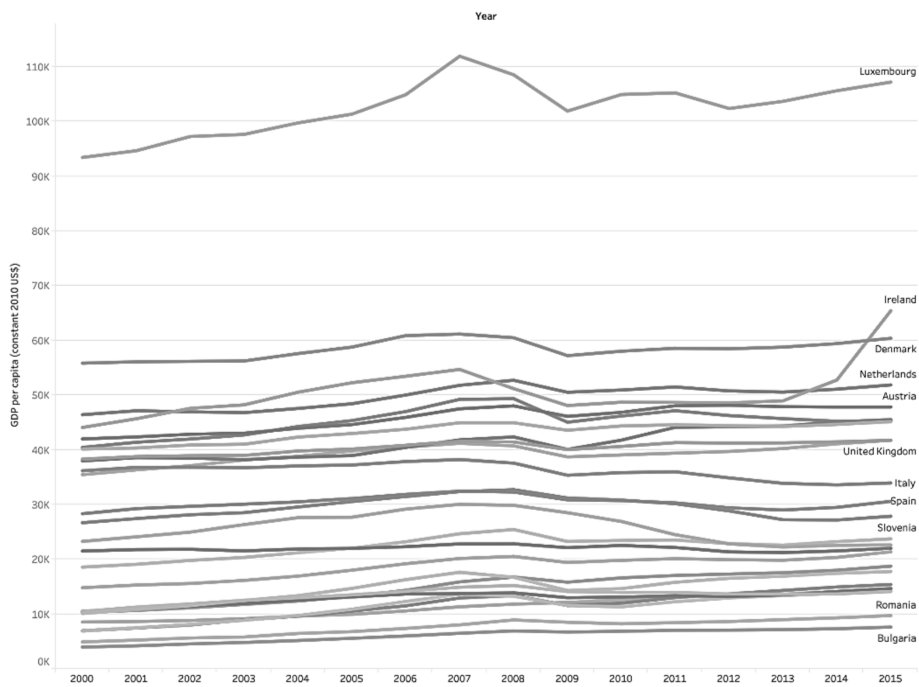
It has been argued generally that the correlation of economic activities between regions grows stronger. In this subsection, an empirical study of the convergence of real GDP per capita of the selected countries in the region is conducted. The selected period (years) for analysis are the years 2000 and 2015 and it explores the impacts of innovation capability on economic convergence using the inverse centroid distance among different regions as a weight matrix in a spatial econometrics model (see Baumont, Ertur and LeGallo, 2002). The choice of the beginning (2000) and end (2015) of the period of the study is considered significant given that spatial analysis is performed for each year. Presenting all results for the 16-year period (2000–2015) will require the use of additional space in this dissertation to present maps and regression results per year. However, Moran's I is calculated for the years 2000, 2005, 2010 and 2015 (see section 4.8) to show the regional per capita GDP convergence trend over the study period. Meanwhile, spatial data analysis and regression results are only presented for 2000 and 2015.

In the spatial econometric model, the maximum likelihood method is used. The development of countries is closely linked with and affected by the economies of neighbouring countries and those further afield. If the per capita GDP growth rate in economically backward countries is higher than that in developed countries, there is β convergence of the regional economy. According to Anselin (1997), to select a spatial lag and spatial error model, the criteria is: if the Lagrange Multiplier lag is statistically more significant than the Lagrange Multiplier Error in the spatial econometric model, the spatial lag model is selected. Conversely, if the Lagrange Multiplier Error is more significant than the Lagrange Multiplier Lag statistically, the Spatial Error Model is chosen (see subsection 4.7.2 and 4.7.3). The question in focus here is whether innovation capability and economic growth clusters and if space matters in the above association, what kind of model can be used to explain the factors that make that possible?

The data on GDP per capita, R&D expenditure and number of patents is from the World Bank Indicators and OECD, while the geospatial data is from Eurostat. Geospatial data or geographic information is data or information that identifies the geographic location of features and boundaries on earth such as natural or constructed features, oceans and more. Spatial data is typically stored as coordinates and topology and this data can be mapped. The Dependent Variable is GDP per capita. The Independent Variable is R&D expenditure and number of patent applications. Population is used as a controlling variable. It must be noted that for some countries included in the spatial analysis, some data were missing, affecting the outcome in the maps generated but not significantly affecting the results of the test overall.

Among the 26 countries in this study, Luxembourg recorded the largest GDP per capita over the years 2000–2015. Figure 20 shows GDP per capita for the 26 EU countries, between 2000 and 2015.

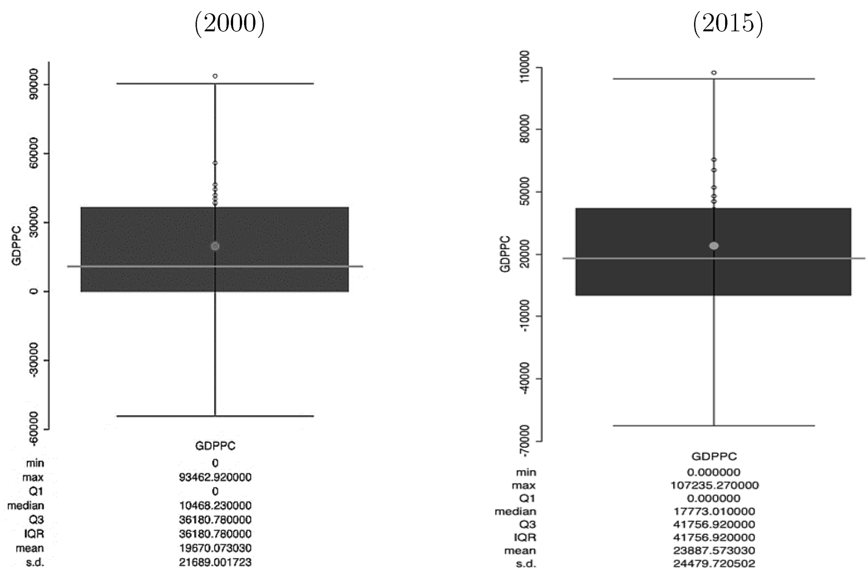
Figure 20. EU countries, GDP per capita, 2000-2015. Source: Composed by the author based on WBI data.



In terms of number of patent applications among the 26 countries in the EU region, Germany continued to dominate (207,908 non-resident patent applications and 770,464 resident patent applications), followed by United Kingdom (138,576 non-resident patent applications and 280,139 resident patent applications), followed by France in 2015. By way of research and development expenditure (as a percentage of GDP) in 2015 for the selected EU countries, Denmark (3.07%) recorded the highest share of GDP dedicated to R&D activities, followed by Austria (3.04%) and Germany (2.92%).

The first step in the spatial tests was to check if the data is normally distributed. Figure 21 shows the distribution of the data for the years 2000 and 2015:

Figure 21. Boxplots showing normality of data (2000 and 2015). Source: Composed by the author based on WBI and OECD data.

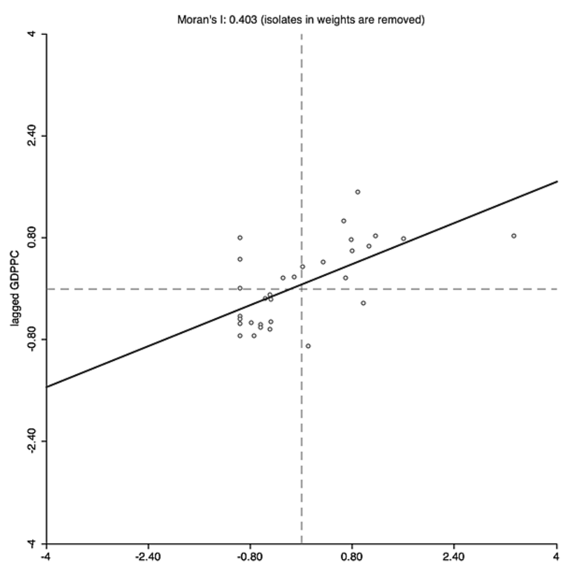


The green circle is the average value of GDPPC. The red area indicates about a 25 per cent to 75 per cent range of values.

Meanwhile, the orange line is the median value. The black lines show the normal distribution of the data, while the one circle outside the black lines shows outliers. Evidently, there are few outliers and the data is normally distributed with little to no skewness for both years, indicating no problems with error variance and standard errors.

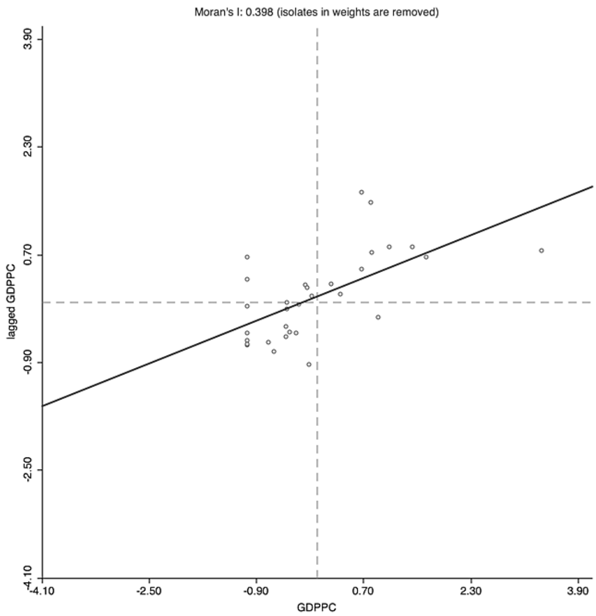
With that satisfied, the Moran's Scatter Plots show a moderate/high autocorrelation in the research region for GDPPC. The question now is whether this is significant. For the year 2000, Moran's I test value = .403, p = .0060. At 999 permutations, the pseudo p-value is 0.006000 ($p<0.05$); therefore, in this instance, the p-value is significant (see Figure 22).

Figure 22. Moran's, I scatter plot - 2000, EU Region (26 countries). Source: Composed by the author based on OECD, WBI data.



For 2015, Moran's I test value = .398, p = .01. At 999 permutations, the pseudo p-value is 0.01000 ($p<0.05$); therefore, in this instance, the p-value is significant for 2015 (see Figure 23).

Figure 23. Moran's, I scatter plot - 2015, EU Region (26 countries). Source: Composed by the author based on OECD, WBI data.



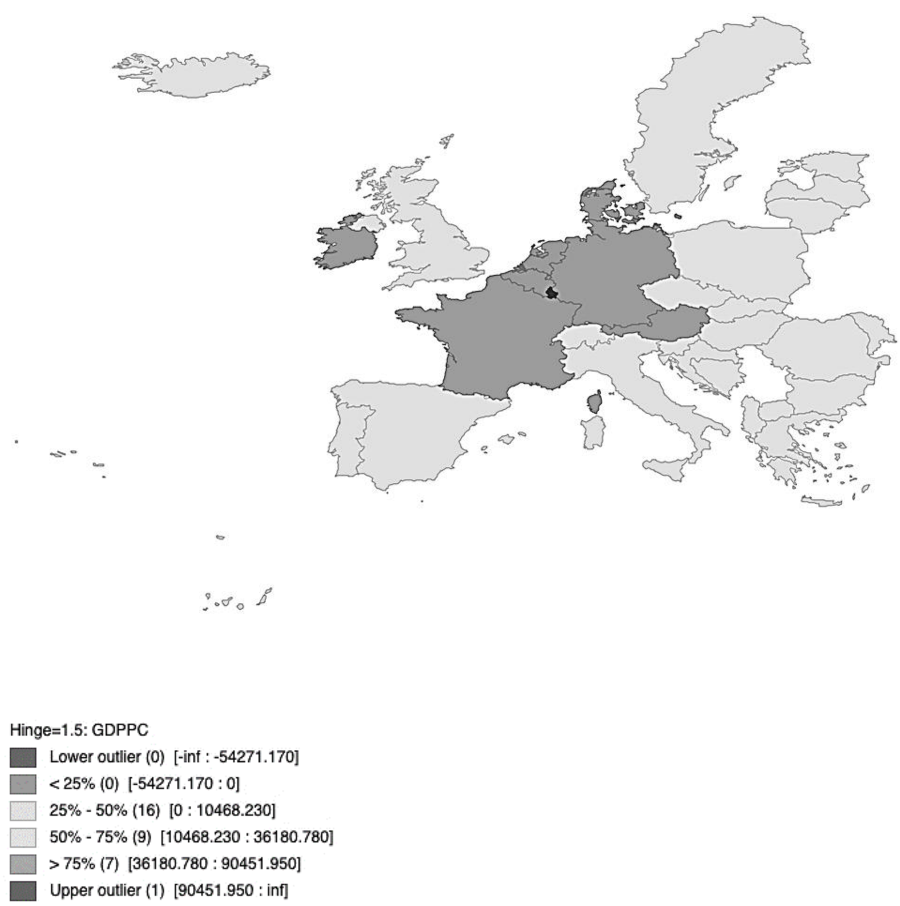
[Permutations = 999; pseudo p-value = 0.01000; I: 0.3980; E[I]: -0.333; Mean: -0.0326; SD: 0.1541; z-value: 2.7930]

The values from calculating Moran's I for 2000 and 2015 all showed p-values as significant, suggesting that there is clustering in the EU region. But where in the EU region? To investigate this further, a test is conducted to establish regional clustering and show significant spatial clusters and outliers by country. Therefore, Significance Maps and Cluster Maps are considered and discussed for both 2000 and 2015. Tracts refer to spatial units. These are statistical units about which locational information is compiled, derived, reported, and compared in the geospatial model using geographic data, including coordinates and other areal units.

First, the local spatial autocorrelation analysis (LISA) cluster map shows how the attribute GDP per capita clusters. The red colour shows tracts where high rates cluster with high rates. The blue shows where low rates cluster with low rates. The orange shows a mix of high and low.

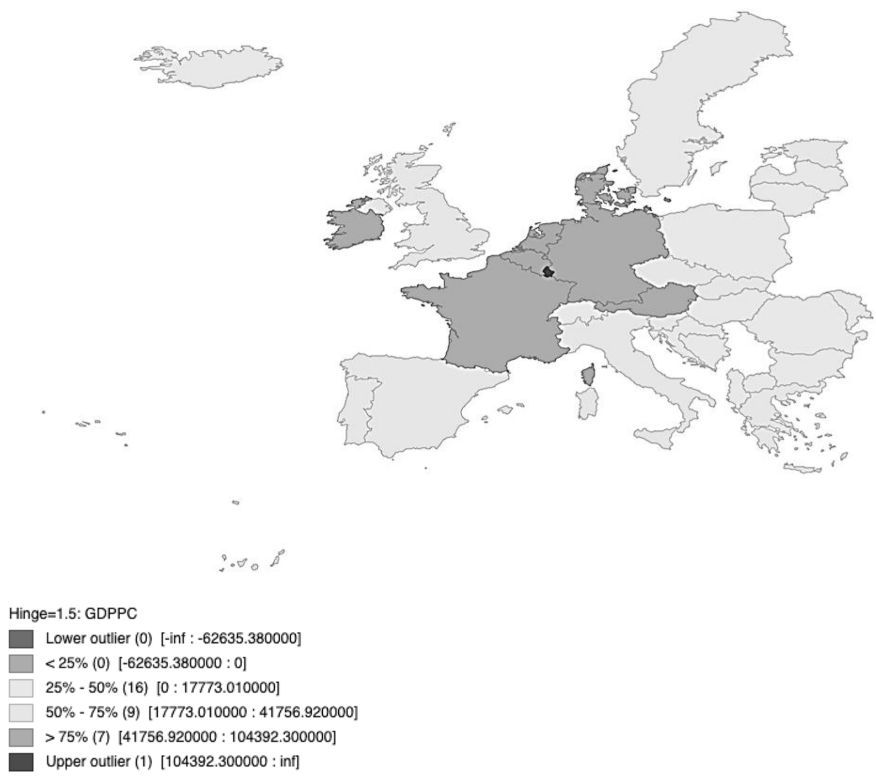
For the year 2000, Estonia is located in the blue tract where low rates cluster with low rates (Hinge =1.5 GDPPC: 25%–50%). Meanwhile, the red tract is western Europe (e.g. France and Germany) and the upper outlier is located in the red tract (see Figure 24).

Figure 24. Cluster map for EU region (GDPPC) - 2000. Source: Composed by the author based on WBI, OECD and Eurostat data.



By 2015, Estonia is located in the orange tract where high rates cluster with low rates (Hinge =1.5 GDPPC: 50%–75%). Figure 25 shows the LISA cluster map for 2015. The upper outlier is still situated in the same place as in 2015. The Western European countries (such as France and Germany) are still located in the red tract, where high rates cluster with high rates. However, Latvia and Lithuania, both countries neighbouring Estonia are still in the blue tract in 2015.

Figure 25. Cluster map for EU region (GDPPC) - 2015. Source: Composed by the author based on WBI, OECD and Eurostat data.



The LISA significance maps for both 2000 (see Figure 26) and 2015 (see Figure 27) show significant results by tract. Western Europe reflected the most significant clustering results in 2000. This did not change in 2015. Ireland and Sweden are considered neighbourless in the geospatial analysis.

Figure 26. Significance map for EU region (GDPPC) - 2000. Source: Composed by the author based on WBI, OECD and Eurostat data.

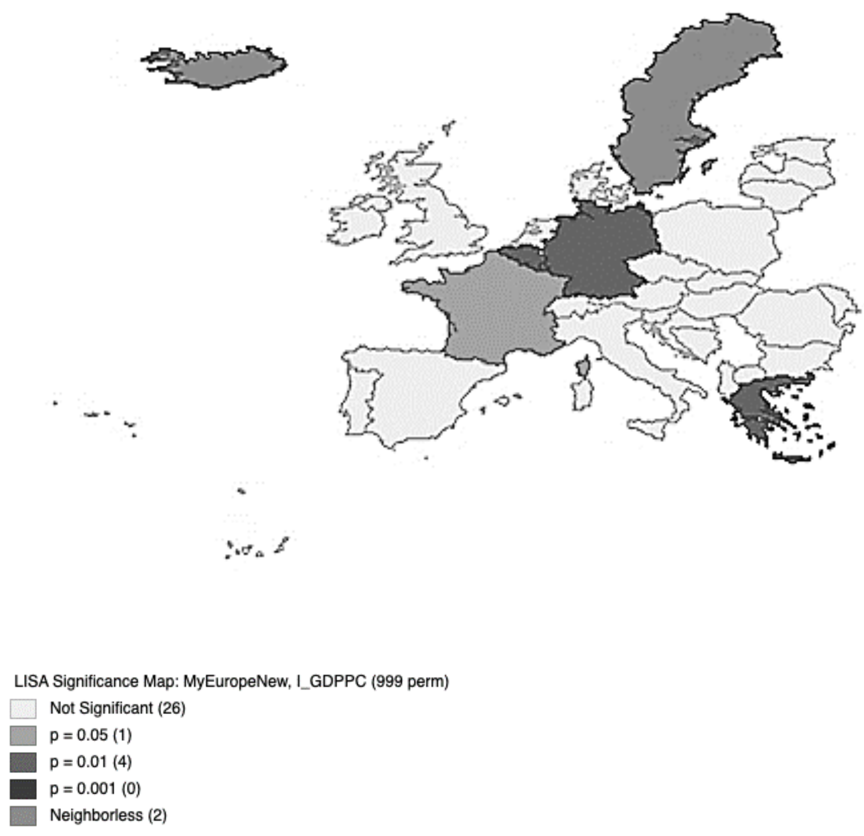
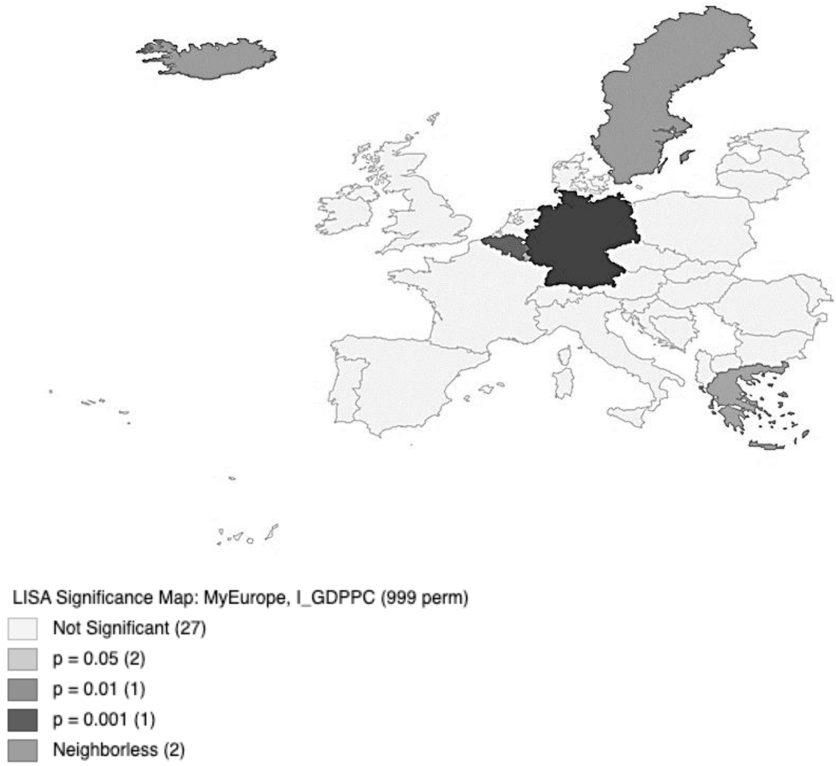


Figure 27. Significance map for EU region (GDPPC) - 2015. Source: Composed by the author based on WBI, OECD and Eurostat data.



Using Moran's I tests, regional clustering is established, and economic convergence confirmed. There is unequal growth in the EU region, which is converging, as suggested by the results of the analysis, and therefore the innovation convergence hypothesis (see section 2.4.5) holds true in this sense. The spatial statistical analysis shows that in the EU regional economic development process, there is significant local spatial clustering and spatial dependency. There is a trend of absolute and conditional convergence (Yang, Zhao and

Zhang, 2017) in the EU region, the effect of which may be more obvious in the longer term than the shorter term.

To summarize, using the inverse distance between the different countries in the EU region as a weight matrix, the per capita GDP of 26 EU countries were analysed for 2000 and 2015. The results suggest that EU regional economic convergence is consistent with the prediction of the neoclassical growth model. The EU region is undergoing economic transformation, so how to control and narrow the regional development gap through effective regional R&D expenditure and common innovation policy applications; macroeconomic regulation is not only key but an important problem that needs to be resolved. Romer (1990) suggested that the level of human capital development has to increase to increase innovation capability regionally. Further attention has to be paid to the spatial interaction mechanism to make use of the regional innovation resource endowment and differences in innovation ability to reduce the gap in regional economic development.

4.7.2. Regression (OLS Estimation)

The summary of the OLS regression estimation are presented in the Table 22.

Table 22. Regression (OLS), EU countries (2000 and 2015). Source: Composed by the author.

Item/Year	**2000**	**2015**
Dependent Variable:	GDPPC	GDPPC
Number of Observations:	33*	33*
Mean dependent var:	19670.1	23887.6
Number of Variables:	4	4

S.D. dependent var:		21357.9		24106
Degrees of Freedom:		29		29
R-squared:		0.466		0.474
Adjusted R-squared:		0.410		0.420
Sum squared residual:		1.03629e+09		1.00776e+10
Sigma-square:		2.77113e+08		3.47503e+08
S.E. of regression:		16646.7		18641.4
Sigma-square ML:		2.43524e+08		3.05382e+08
S.E of regression ML:		15605.3		17475.2
F-statistic:		8.440		8.727
Prob(F-statistic):		0.0003		0.0002
Log likelihood:		-365.452		-369.187
Akaike info criterion:		738.904		746.373
Schwarz criterion:		744.89		752.359
2000				
Variable	**Coefficient**	**Std.Error**	**t-Statistic**	**Probability**
CONSTANT	3795.32	4560.45	0.832226	0.412
RND	22725.2	4983.08	4.56048	0.000
PATENTS	-0.334	0.453	-0.739	0.465
*POP_CNTRY	1.49126e-05	0.00026	0.0568	0.955
2015				
CONSTANT	3232.6	5520.39	0.585576	0.56269
RND	18218.1	3854.51	4.72645	0.00005
PATENTS	0.151	0.422	0.357	0.723
*POP_CNTRY	2.42709e-05	0.000	0.098	0.922

*Population of Country is used as a control variable

The number of observations (33) represent spatial weights (based on R&D and PA as input variables), which are also based on the assumption that in this spatial analysis, countries closer to each other have a greater influence than countries farther away from each other. These spatial weights are a measure of this influence. This checks to see if tracts are indeed next to and clustering with other tracts based on GDP per capita values. The 33 observations represent unique numbers generated for each tract in the geospatial modelling process. These are weights which take the average of a measurement in a spatial unit (tracts) around the EU region.

From Table 22, it can be suggested that for both 2000 ($p<0.01$) and 2015 ($p<0.01$), R&D expenditure was significant in predicting EU regional GDP per capita but not number of patent applications.

4.7.3. Regression diagnostics

The results of the regression diagnostics are presented. The multicollinearity condition number is 5.089040 for 2000 and 4.268415 for 2015. Both values are not above 5, which is acceptable given the relatively small data size used in the spatial analysis. The results suggest that the independent variables are not highly correlated with one another and provides correct estimates in the model. Table 23 presents the results of the test on normality of errors. The Jarque-Bera test is a goodness-of-fit test of whether the data has skewness and kurtosis matching a normal data distribution. If the test statistic is far from zero, it signals the data does not have a normal distribution. The results show statistical significance ($p<0.01$) for both years 2000 and 2015. This suggests goodness-of-fit.

Table 23. Test on normality of errors (2000 and 2015). Source: Composed by the author.

Year	TEST	Degrees of Freedom (DF)	VALUE	PROB
2000	Jarque-Bera	2	71.5073	0.00000
2015	Jarque-Bera	2	253.2651	0.00000

In the sense of Anselin (1998), in tests with spatial data, the significance of the **Lagrange Multiplier (LM)** and **Robust LM tests** are paramount. The Lagrange Multiplier tests for the presence of spatial dependence and the Robust LM tests for which lag or error the spatial dependence variable could be at work in the study. As advised by Anselin, the Robust LM test has a lag of 5.4389, p-value of 0.019 ($p<0.05$) for 2000. For 2015, the Robust LM test has a lag of 4.2453 and a p-value of 0.039 ($p<0.05$), which is statistically significant in both cases. The Lagrange Multiplier p-values were not significant ($p>0.05$) for both years. **Therefore, the Robust LM test error values 2.8495 for 2000 and 1.6260 for 2015 are chosen** as advised by Anselin (1998). Table 24 shows the results of the diagnostics for spatial dependence.

Table 24. Diagnostics for spatial dependence. Source: Composed by the author.

TEST	2000			2015		
	MI/DF	VALUE	PROB	MI/DF	VALUE	PROB
Moran's I (error)	0.0401	0.5383	0.5904	0.1157	1.0046	0.31511
Lagrange Multiplier (lag)	1	2.6552	0.10321	1	3.166	0.07518
Robust LM (lag)	1	5.4389	0.01969	1	4.2453	0.03936
Lagrange Multiplier (error)	1	0.0658	0.7975	1	0.5467	0.45967
Robust LM (error)	1	2.8495	0.0914	1	1.626	0.20226
Lagrange Multiplier (SARMA)	2	5.5047	0.06378	2	4.792	0.09108

For Weight Matrix: Myeurope (row-standardized weights)

Table 25 shows the summary of the output of the test of the spatial error model using maximum likelihood estimation, based on the spatial dependence analysis. The **Akaike info criterion** is important for spatial regression and reports on the goodness of fit for the models. For 2000, the value is 738.582; for 2015, the value is 744.722. The lower the value for the years measured, the more accurate the test is assumed to be. The **R-squared values** are equally important. For 2000, the R-squared is .514. More than 50% of the variance in regional GDP per capita is explained by R&D expenditure and number of patent applications, suggesting that the model is effective. The coefficient values for R&D expenditure for 2000 (21737.2) and 2015 (16164.5) suggests that the R&D expenditure variable is strong in the model. For every R&D expenditure unit increase, there is a corresponding unit increase in regional GDP per capita.

The Table 25 also shows the random coefficients, which include the results of the diagnostics for heteroskedasticity in the data analysed for the 26 EU countries. The Breusch-Pagan test for heteroskedasticity tests the null hypothesis that the error variances are all equal versus the alternative that the error variances are a multiplicative function of one or more of the variables in the analysis. In this, the alternative hypothesis is that the bigger the predicted value of the per capita GDP for both years, the bigger the error variance. There are variabilities in the per capita GDP levels in the countries selected for this analysis, with a propensity to result in heteroskedasticity. For 2000, the value is 4.89 and for 2015, the value is 2.85, indicating that heteroskedasticity was probably not a problem (or at least if it was a problem, it was not a multiplicative function of the predicted values).

Table 25. Spatial error model - maximum likelihood estimation. Source: Composed by the author.

Item/Year	**2000**	**2015**
Dependent Variable:	GDPPC	GDPPC
Number of Observations:	33*	33
Mean dependent var:	19670.07	23887.57
Number of Variables:	4	4
S.D. dependent var:	21357.85	24105.96
Lag coeff. (Lambda):	29	29
R-squared:	0.514477	0.522705
R-squared (BUSE):		0.358347
Sq. Correlation: -		0.420109
Sigma-square:	2.21475e+08	2.77E+08
S.E. of regression:	14882	16654

Log likelihood:	-365.29	-368.38
Akaike info criterion:	738.582	744.772
Schwarz criterion:	744.568	750.758

	2000				2015			
Variable	Coefficient	Std. Error	z-value	Probability	Co-efficient	Std. Error	z-value	Probability
CONSTANT	407.902	3476.26	0.117339	0.90659	6266.06	5620.42	1.11487	0.2649
RND	21737.2	3972.69	5.47166	0	16164.5	3618.12	4.46765	0.00001
PA	0.23038	0.36835	0.625438	0.53168	0.329799	0.350713	0.940369	0.34703
POP_CNTRY	1.98E-06	0.00021	0.0091	0.99	-1.44E-05	0.00021	0.067	0.94652
LAMBDA	-0.487028	0.166926	-2.91764	0.00353	0.358347	0.166318	2.15459	0.03119

Regression Diagnostics						
Diagnostics for Heteroskedasticity						
Random Coefficients						
Test	**2000**			**2015**		
	Df	**Value**	**Prob**	**Df**	**Value**	**Prob**
Breusch-Pagan test	3	4.893	0.17981	3	2.8512	0.41515
Diagnostics for Spatial Dependence						
Spatial Error Dependence for Weight Matrix: MyEurope						
Test	**Df**	**Value**	**Prob**	**Df**	**Value**	**Prob**
Likelihood Ratio Test	1	0.3217	0.57058	1	1.601	0.20576

To conclude on the Spatial Regression Tests, it is important to compare the coefficients on both the OLS test and the Error Regression models. Comparing the R-Squared values, Akaike Info Criterion and Schwarz Criterion, it can be noted that all values went down in the Error Regression tests, but for the R-squared values for both years, 2000 and 2015. This suggests that the Error Regression tests are stronger and more accurate. In addition, the R&D expenditure variable continues to remain significant, suggesting that when the spatial weights are taken into consideration in the model (Spatial Lag Model), the spatial regression becomes noticeably stronger in predicting the GDP per capita than a simple OLS Regression. Table 26 shows the comparison of the OLS results with the error regression models. To end this section, **R&D expenditure is a significant predictor of GDP growth in the EU region, specifically, in relation to the 26 countries in the study**.

Table 26. Comparing OLS vs error regression models (2000 and 2015). Source: Composed by the author.

	2000		**2015**	
Coefficients	**OLS**	**Error**	**OLS**	**Error**
R&D	22725.2	21746.7	18218.1	16164.5
PA	-0.334	0.232	0.151	0.329
R-Squared	0.466	0.514	0.474	0.522
Akaike Info Criterion	738.90	736.58	746.37	744.77
Schwarz Orientation	744.89	741.07	752.35	750.75

4.8. Inferences from Smoking Gun Tests

The inferences and summaries from the results of the smoking gun tests are presented in Table 28. In this, alternative choices and counterfactual outcomes (see section 3.6) are analysed.

Inference A1: For Estonia only, a positive relationship could not be established between R&D expenditure, number of patent applications and economic growth. Therefore, this is interpreted as **somewhat unusual** – a straw-in-the-wind test that makes Hypotheses 4 and 5 more plausible without confirming them. R&D expenditure and number of patent applications do not have a significant role in predicting GDP per capita and economic growth of Estonia. In the case of Estonia, in answering RQ2, these two growth factors cannot be considered as innovation and technology-led economic growth determinants, in this sense.

Inference A2: Human capital development and technological innovation are interpreted as **exceptionally unusual** innovation- and technology-led economic growth determinants. Human capital development and technological innovation are inextricably linked to innovation- and technology-led economic growth and economic development. Human capital development is an innovation- and technology-led economic growth determinant in the case of Estonia. The evidence gathered and submitted (see section 4.4 and section 4.5) support the fact that human capital development in Estonia has remained the same, at very high levels, during the period 2000 to 2015, as suggested by the HDI values. Estonia has, for example, ranked in 18th to 26th place on the networked readiness index between 2000 and 2015, which are signals of growth consecutively leveraged on ICTs.

Inference A3: Regional innovation capability is interpreted as **exceptionally unusual** in relation to regional economic growth. Regional Innovation Capability is an innovation- and technology-led economic growth determinant. The results of the panel data analysis without the spatial effects confirmed the innovation convergence hypothesis for the EU region. The introduction of the spatial effects further confirmed this finding, that there is unbalanced growth and clustering in the EU region, which is impacting economic growth levels across the region. The most important aspect of this is the increase in regional innovation capacity as a result of common policy and other innovation applications.

Table 27. Moran's, I Index of EU regional per capita GDP, 2000-2015. Source: Composed by the author.

	2000	**2005**	**2010**	**2015**
Moran's I	0.4028	0.372374	0.373	0.3980

From Table 27 and Figure 28, Moran's I indices for the EU regional per capita GDP for 2000–2015 all passed the significance test below the level of 5 per cent (Elhorst, 2003; Case, 1991; Baltagi and Li, 2006; Holtz-Eakin, 1994). Although there is fluctuation in the Moran's I Index, all the values are above 0.3. This indicates that regional economic activities in the EU are not in a random state, but rather demonstrate the phenomenon of clustering in geographical space, and in the study period, this agglomeration demonstrates first a rising trend, but later a diminishing trend. In other words, EU per capita GDP has a strong spatial correlation and the EU countries with relatively higher economic development are adjacent to each other while economically backward EU countries also tend to be adjacent to each other.

Figure 28. Moran's I Index 2000-2015. Source: Composed by the author.

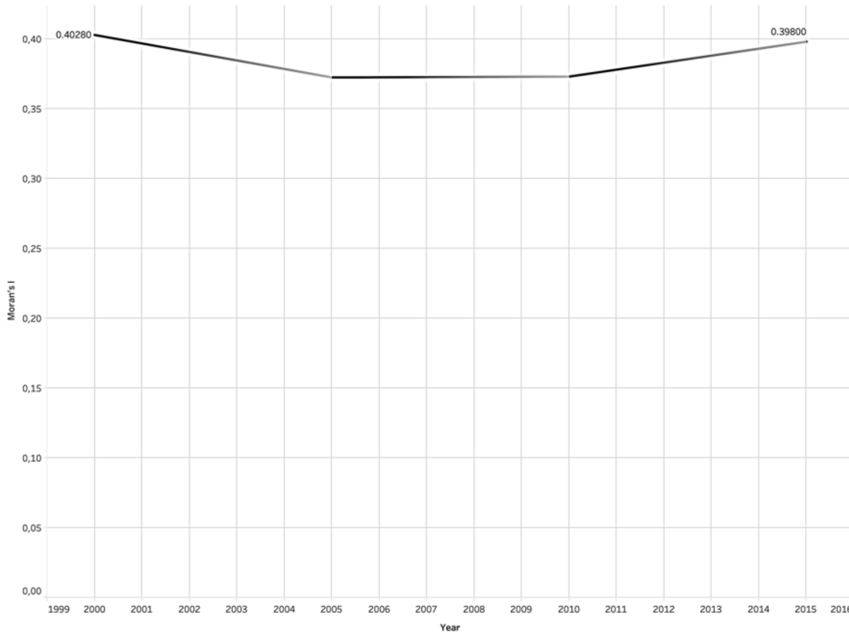


Table 28. Inferences summary for smoking gun tests. Source: Composed by the author.

Innovation and technology-led Economic Growth Factor	**Innovation promoting effects**	**Economic Growth as**	**Inference**
Domestic: • Patent System and Enterprise R&D Expenditure • Human Capital Development; and Technological Innovation	• Shifting growth models towards consumption, services, higher value-added manufacturing and innovation; Productivity • Accumulation of human; capacity Education and Learning; rapid in-country innovation diffusion	• Double-digit GDP growth rates and macro-economic development • Increased Domestic Technology Absorptive capacity • Information Society and Path dependence; Modernization	Hypotheses 1-3 provide ample evidence and meet the sufficiency but not necessary criterion for accepting causal inference in the sense of Beach and Pedersen (2013). The above evidence from the tests of these hypotheses passes Hypotheses 2 and 3, weakening Hypotheses 4-5 for that matter. Hypothesis 1 is failed. The method of elimination here is especially relevant because, the statistical procedures performed in this work using data collected from World Bank, OECD, UN and EU provide smoking gun evidence. Additionally, most of the assumptions underlying these hypotheses have been tested in the past and passed as well, supporting the thesis of this work.
Regional: • Regional Innovation Capability • Technologies with trade and investment	• Conditional Convergence Hypothesis	• Regional Economic Convergence and Regional Economic Development	

Alternative Inference A1$_1$: R&D expenditure, number of patent applications are interpreted as **somewhat unusual**, suggesting, but hardly confirming a relationship between R&D expenditure, number of patent applications and economic growth. The relationship is just a coincidence. This is accepted.

Alternative Inference A2$_2$: Human capital development and technological innovations are interpreted as somewhat unusual, suggesting, but hardly confirming a relationship between the human capital development and technological innovations and economic growth of a nation. This is dispelled.

Alternative Inference A3$_3$: Regional innovation capability is interpreted as somewhat unusual, suggesting, but hardly confirming a relationship between regional innovation capability and economic growth. This is dispelled.

To conclude, the study confirms some theoretical expectations, and the inferences as a result lend ample credence to the assumptions of Hypotheses 2–3 but does not confirm Hypothesis 1.

4.9. Chapter summary

Chapter 4 presented the first set of evidence in support of the Primary Hypotheses (see section 3.5). Smoking gun tests were conducted. The main variables were R&D expenditure, and number of patent applications, human capital development and technological innovation. Here, it became evident that R&D expenditure and number of patent applications were not significant in explaining economic growth in Estonia over the study period and suggest that they are not innovation- and technology-led economic growth determinants in the single case of Estonia. Meanwhile, R&D was a significant input variable in the economic convergence situation experienced in the EU region during the same period. Number of patent applications, it was determined, was not significant in explaining economic growth in the EU region. The submission of evidence was preceded by demographic and socio-economic information and a summary of macroeconomic developments in Estonia over the study period 2000 to 2015.

The aim of the tests performed was to provide empirical evidence in relation to the role of R&D expenditure and number of patent applications on economic growth first in Estonia only, and then in a sample of EU countries (26 countries). The results show that a significant relationship exists between the input variable, R&D expenditure, in the EU region but not for Estonia. However, what remains to be considered more closely are those qualitative issues underlying R&D expenditures by governments in the region and also whether a significant relationship can be established between the number of patent applications and economic growth in the region, and whether the relationship is significant or otherwise. Kacprzy et al. (2017) studied innovation and economic growth in the European Union for 13 countries but with a different focus and concluded that there may be no single recipe for growth for all EU countries and that growth strategies may differ across member states, and therefore growth strategies should address country-specific settings and development challenges. They also caution against improper policies in this regard for the region.

To conclude, contrary to Romer's (1990) prescriptions, this study's assumption about endogenous growth theory in relation to R&D expenditure and number of patent applications (specifically for Estonia) could not be confirmed, in that the results do not support endogenous growth theory that R&D activities positively affect economic innovation, and economic growth in the long run for Estonia. Regional capability is linked positively to economic convergence, confirming the innovation convergence hypothesis, (see section 2.4.5) all the same. The results also suggest a strong positive association between human capital development and technological innovation without necessarily confirming the hypotheses.

5. FINDING EVIDENCE FOR RIVAL HYPOTHESES AND DISCUSSION OF INFERENCES

This chapter presents the second set of findings from data analysed using the matrix for assessing the certainty and uniqueness of evidence as proposed by Beach and Pedersen (2013). Section 5.1 presents the findings from analysing the ICT infrastructure in Estonia using the hoop test with an interpretive case study method (see section 3.4) to describe and explain the research phenomenon that ICT infrastructure, as an indirect innovation- and technology-led economic growth factor, has a positive impact on economic innovation (see section 2.4). Section 5.2 presents evidence from analysing technology governance practices and innovation policies rolled out, which set the stage for technological developments, as hypothesized, to have a positive impact on economic innovation. The straw-in-the-wind test (see section 3.4) was used with an interpretive case study method. The analysis of evidence gathered in support of these rival hypotheses sought to answer RQ3.

RQ3: What are the indirect innovation- and technology-led economic growth determinants of Estonia's economic development since 2000?

5.1. Hoop test of ICT infrastructure in Estonia

In this section, an interpretive case study method is engaged with a hoop test (Beach et al, 2013). Hypotheses 4 is re-stated:

- **H_4:** ICT infrastructure has a significant positive impact on economic innovation.

Economic innovation is specified in section 2.4. In clarifying the concept of economic innovation, it was observed that in the innovation- and technology-led economic growth model (see section 2.1 about growth models), inputs are innovation- and technology-led economic growth factors, with outputs being development. The most important assumptions are that knowledge accumulation, technological innovations and human capital development remain endogenous to the economic growth model. ICT infrastructure (see subsection 2.6.1) is an important element in the innovation- and technology-led economic growth model. Romer (1990) argued that there are positive effects of investing in ICT as a country. Westmore (2014) asserts that there is a relationship between R&D expenditure and the national economy when new technologies are introduced. Added to this, more recent scholars, such as Wong, et al. (2005), also examined the relationship between technological innovation and economic growth when new technologies are introduced in a country. This suggests that ICT infrastructure is important to economic innovation – there is a shift in the economic growth model where tangible components are substituted for intangibles such as knowledge accumulation and technological innovation.

The structure of the Estonian economy between the 1960s and 1988 was tilted more towards industry (see Appendix 6). The data suggests that the structure of the Estonian economy was transformed between 2000 and 2015 (see section 4.2). The evidence as provided by the NRI, which measures annually and ranks countries based on how well they leveraged ICTs for development (see section 4.5), showed that Estonia was technologically successful, shifting from a low-technology country before 2000 to a top performing advanced-technology country by 2015. Estonia was touted as having made tremendous technological progress. Appended to this work is a trend analysis of Estonia's rankings on the NRI, particularly between 2012 and 2015. Due to changes in the structure of the NRI, comparison of data against the 2001 to 2011 data would be spurious (See Appendix 5).

Kattel (2018), among others, has observed that the data infrastructure, x-road and compulsory national ID system were major contributing factors to the Estonian digital success story. Some commentators have argued that there exists a complex relationship between ICTs and socioeconomic performance, and that their causality is not fully understood or established. Is the data infrastructure platform x-road significant in the digital transformation in Estonia? How does x-road impact economic innovation in this sense?

5.1.1. The x-road and RIA in Estonia

Referred to as the x-road data exchange layer, the deployment of the Estonian information system is considered significant to this dissertation. In the late 1990s, there were fragmented information and manual systems used in both government offices and by citizens. Before accession to the EU in 2004, several ICT projects were running. A single point of failure (SPOF) with a propensity to stop the entire national system (though fragmented) from working was lurking.

To integrate all such resources, a distributed architecture that ensures data protection and monitoring was required in Estonia, without significantly altering the then state infrastructure, and this needed to be implemented using data models and system management technologies that were focused on integration. The result was the establishment of the x-road.

The x-road is a platform-independent data exchange layer that enables secure internet-based data exchange. According to the Information Systems Authority of Estonia (RIA), the system ensures sufficient security for the treatment of queries made to databases and responses received. The x-road infrastructure consists of software, hardware, and organizational methods for the standardized usage of national databases.

The technologies supporting the architecture were WSDL and UDDI for the Services layer, which was composed of parental benefits, vehicular management, and penalties components. The next layer was the data traffic layer, supported by SOAP (XML RPC) LDAP technology. The main components included the security server, central server, mini information system portal (MISP) and the citizen's portal. The third layer was the information systems layer, supported by Java, .NET, Python and SAP technologies. Its components included traffic register, population register and passports register. Table 29 presents a summary of the versions of x-road between 2000 and 2015.

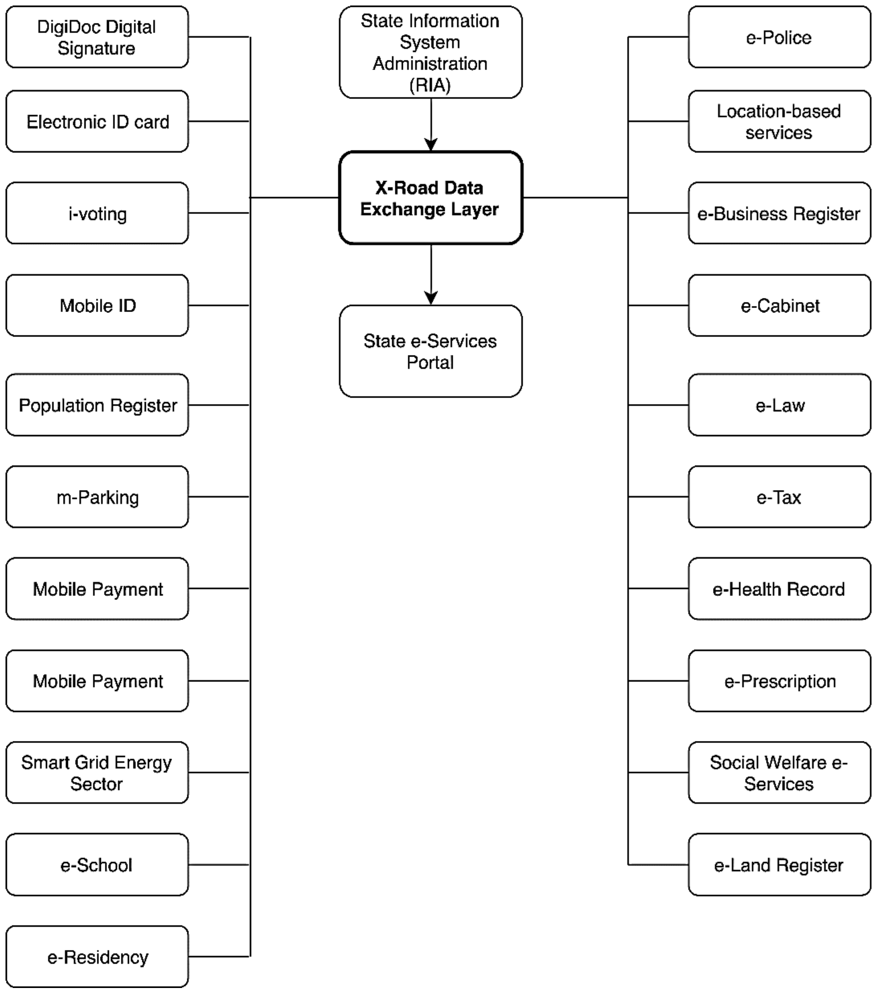
Table 29. X-road versions between 2000 and 2015. Source: Composed by the author based on RIA data.

Version	**Updates**
Version 1.0	2000. XML-RPC
Version 2.0	2002. SOAP RPC/encoded
Version 3.0	2004. Synchronous services
Version 4.0	2006. Security update
Version 5.0	2010. SOAP document/literal wrapped
Version 6.0	2014. federation, External trust service providers

The x-road is simple in terms of management – simple to install and plug into the infrastructure. For example, to connect a new data system to the x-road, a virtual physical secure server, which comes with a local monitoring system, must be installed. Next, to interface x-road with an existing information system, a software adapter server must be installed on a development platform of choice. Thereafter, the service provider can create services in their adapter over the x-road and open servers to their members in the provider's secure server. The service user then creates a solution in their adapter server that connects the service provider's open web services to their own information system. An MISP software (which is meant for the usage of services available on the x-road) can be adopted for using the service.

This very simple user interface comes with mechanisms for user authentication and authorization. According to the RIA, there were over 170 databases offering services over the x-road in Estonia between 2001 and 2014, and over 2000 services were using the x-road, over 900 organizations used the x-road daily in Estonia, and more than 50% of the inhabitants of Estonia used the x-road via the information portal *eesti.ee* and by 2013, over 287 million queries had been made over the x-road data exchange layer infrastructure. The RIA is an important player in the system integration chain. However, data does not pass through the x-road centre nor can it be viewed there. Instead, encrypted data are directly transferred through secure servers from one information system to another. The x-road's secure servers issue certificates to secure servers and provides a list of trusted certificates to systems connected to the x-road. Figure 29 shows the components of this ecosystem managed by the RIA. The components of Estonia's information system are explained and appended to this work (see Appendix 7).

Figure 29. The x-road components. Source: Composed by the author based on RIA data.



The RIA reports that in 1997, e-Governance was introduced as a module of the Estonian information system. e-Tax was introduced in 2000, the x-road in 2001, compulsory digital ID in 2002, i-Voting in 2005, blockchain technology and e-Health in 2008 and by 2014, e-Residency. It is projected that more modules, including Reporting 3.0, Healthcare 4.0, Real-Time economy and Industry 4.0, among others, will be added.

The x-road is an integrating component of the Estonian information system. The significance of this ICT infrastructure, as a technical system component, cannot be emphasized enough. Several countries are on the verge of accepting the impact of integrating multiple platforms into a single layer in their national information systems. Estonia's x-road has been so successful internally, it is now an export commodity to other countries, both near and far. From 2008, the Estonian Government started exporting the x-road to other countries, which are also implementing splinter information systems. These countries include Benin, a country located on the western coastline of Africa and Namibia (also an African country), which has already adopted this. The Estonian IT company, Cybernetica, has been at the forefront of the x-road export project. In addition, the Estonian data exchange platform has so far been developed and deployed in Finland and by 2013, also Ukraine, Namibia, Haiti, Kyrgyzstan, Azerbaijan, Faroe Islands and Cayman Islands. By the end of 2018, Iceland had adopted Estonia's x-road for implementation (announced early in 2019).

Before Estonia started exporting the x-road, the Estonian Government issued a regulation 'data exchange layer of information systems' (2008; Infosüsteemide andmevahetuskiht), which stated that the European Union Public Licence (EUPL) will be the official licence to distribute the x-road. The elaboration of the European open source licence, EUPL, was commenced in 2004 by the European Commission (Dusollier, 2007, p. 1429). The preamble for the EUPL brought out that its purpose is to promote the interoperable delivery of European e-Government services to 26 public administrations, businesses and citizens; therefore, advancing the use and distribution of state-owned ICT solutions inside the EU. Through EUPL, the licensor gives the licensee a world-wide, non-exclusive, royalty-free, sub-licensable licence to use, reproduce, modify, distribute, communicate to the public, lend and rent the work. A EUPL was used to provide documentation, know-how, and x-road source code to Finland in 2013.

The effects of ICT infrastructure on the development of nations has been studied in several empirical works, focusing both on countries leading the "technological revolution" – the United States of America; for example, Jorgenson and Stiroh (2000); Cummins and Violante (2002); Oliner and Sichel (2000); and European countries – Daveri (2002); Colecchia and Schreyer (2002); Jalava and Pohjola (2002), among others. Their studies have suggested that ICTs have a strong impact on GDP growth, concluding that the ICT industry is more productive than other industries producing traditional investment goods, and that an economy with a higher fraction of resources allocated to the production of ICT assets typically shows higher growth rates, according to Morlinari and Torres (2018).

5.2. Inferences from hoop test of ICT infrastructure

Inference: With a stronger assumption based on the role and implementation of ICT infrastructure, that ICT infrastructure could have been instrumental for economic innovation.
Alternative Inference: With a weaker assumption about the role and implementation of ICT infrastructure, there is some doubt about the link to economic innovation but does not preclude it.
Summary: With a stronger assumption, this is a hoop test which fails to confirm $\mathbf{H_4}$; with a weaker assumption, it is a straw-in-the-wind test which casts doubt on $\mathbf{H_4}$.

ICT infrastructure is a necessary innovation- and technology-led economic growth factor and precondition in the transformation of national economies. Estonia's case in not unique in this sense. What is unique is that in the specific case of Estonia, this ICT infrastructure remains a flagship product already being exported to other countries. Yet, the issue at hand as hypothesized earlier in this section is whether ICT infrastructure has a significant impact on economic innovation in Estonia. The evidence provides strong signals about technological transformation and digital success. Whether these could be associated with the x-road, as an ICT infrastructure (input variable) analysed to meet the sufficient or necessary condition in the sense of Beach and Pedersen (2013), is considered dependent on the interpretive understanding of the data (Angen, 2000). While the assumption of a connection between investment in ICT infrastructure and economic innovation is weak, it indeed cannot be precluded from the narrative in this study.

Several studies have pointed to the impact of ICT investments on economic growth. The most important development from the Hoop Tests is that (1) the ICT infrastructure alone cannot drive economic growth. The social system, in addition to contextual factors, governance principles and design issues are relevant as well. In the sense of Everett Rogers (1962, 1985, 2003), the social system constitutes a boundary within which ICTs diffuse and that the social structure of the system affects how ICT diffuses. For Rogers (2003), a social system is a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. This social system has members or units that may include individuals, informal groups, organizations and/or subsystems. This is important because investments in ICTs must be diffused in social systems to drive economic growth.

While analysing alternative assumptions and inferences, there are arguments strongly against the role of the x-road infrastructure digital success story of Estonia. Some commentators call it a post-project residual, with the possibility of not being the best ICT infrastructure contributing to Estonia's digital success. One such argument notes the Soviet legacy of an outdated industrial structure and widespread aversion to industrialization in Estonia. All the same, these legacies left behind important R&D effects in ICT and other important areas, which are still being leveraged. It can be concluded that the x-road is a good example of a "build or buy" situation. The choice was to build systems from scratch. Individuals and businesses must supply information only once, among other niceties. The current challenge with the x-road, it has been suggested, is secure interoperability of the data systems, rather than having created unified databases and information systems.

Different lines of research have addressed the determinants and patterns of ICT diffusion in a social system. According to, Lee, Hong and Hwang (2017), the diffusion process with ICT includes the stages of introduction, adoption, diffusion and adaptation within an organization or society. Some of these include the impact of the geographic movement of skilled workers on the diffusion of technologies (Scoville, 1951; Landes, 1969). Others have argued that some other institutional factors such as the presence of business trade associations or the use of a common capital-good supplier, have contributed to the diffusion process as well by lowering the cost of acquiring information (Graham, 1956; North, 1958 and 1968; Knauerhase, 1968; Walton, 1970; Saxonhouse, 1974).

The concept of culture has received some attention from information systems researchers since the days of Emery and Trist (1960) and Mumford (1979). The beliefs and values regarding ICTs that permeate societal groups have been examined from a variety of perspectives, such as national, ethnic, organizational and professional culture. For several decades, scholars (such as Bostrom and Heinen, 1977; Markus, 1983) have been challenged to investigate the relationship between ICTs and organizational culture. Some of these researchers identified that some systems that technically work well are resisted by their users, which was an area labelled the system/culture fit and explained in terms of technologies having what is referred to by Markus and Robey (1983) as having questionable “organizational validity”, despite their adequate “technical validity”. Culture against this backdrop is significant in a social system in relation to diffusion.

To end the section, the evidence in support of the rival hypothesis 4 suggests a probable role of ICT infrastructure, more specifically, in the digital success story of Estonia and government investments in ICTs overall. What cannot be confirmed is whether ICT infrastructure in this sense influenced economic innovation and by extension economic growth. Considering this a weaker assumption, **H_4 is a straw-in-the-wind which casts doubt on H_4, strengthening H_1 to H_3, in this sense. H_4 is failed.** This conclusion is assessed further in Chapter 6.

5.3. Straw-in-the-wind test of innovation policy and technology governance in Estonia

In this section, an interpretive case study analysis using the straw-in-the-wind test (see section 3.4) is presented and Hypotheses 5 is re-stated.

> **H_5:** Innovation policy and technology governance have a positive influence on economic innovation.

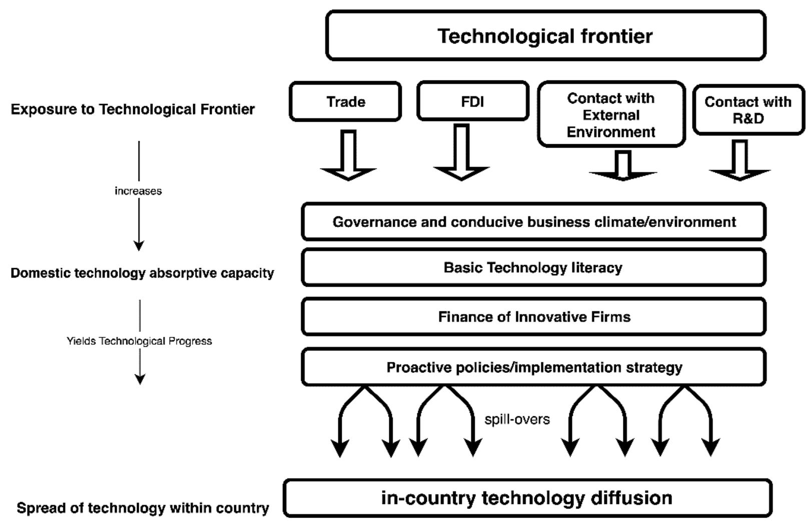
Estonia’s digital success story has been touted globally. What is referred to as the “e-revolution” post 2000 is not in doubt. The question is which factors were coordinated to achieve this digital feat. The role of technology governance and innovation policy (see subsection 2.6.2) in economic innovation has been considered and reported in the literature. Of significance to this work are the conclusions of Morlinari and Torres (2018), who identified resource allocation, including ICT infrastructure, as key to economic growth. Yin and Mao (2017), who made a similar case for China’s economic development, also argued about the importance of resource allocation in the digital transformation process. More specifically, Yin and Mao (2017) concluded that in the case of China, because state-owned firms had command of non-trivial political weights, they could absorb non-trivial level resources, including government subsidies, the allocation of R&D subsidies and other resources for state-owned enterprises (SOEs) and private firms. In their view, this posed a negative effect on resource allocation and overall execution of the digital transformation. How does resource allocation relate to economic innovation?

The allocation problem rests on technology governance and innovation policy implementation. To understand and trace the role and importance of these indirect innovation- and technology-led economic growth factors, a review of the structure of the Estonian economy (see Appendix 6), transformations undergone and the social system becomes useful to identify the place of technology governance and innovation policy in the national development of Estonia. After the Soviet regime, from about 1987, the literature has suggested that the leadership of Estonia sought to reclaim the history of Estonia and to set the pace for a new frontier. Several actions were taken to change the course of the country's history.

5.3.1. Technological progress and economic reformation in the Estonian social system

Technological frontiers, according to the World Bank Report (2008) cited by Aubert et al. (2010), are established when a country's exposure to technology (be they new or upgrades) is improved, typically through trade, foreign direct investments (FDIs), contact with the external environment and R&D activities. These factors are known to increase the domestic technology absorptive capacity of nations. In this, governance and a conducive business climate ought to thrive, basic and advanced technological literacy should be enhanced, innovation begins to receive funding and attention especially through a start-up culture, and, though not the least, proactive policies and implementation strategies to back these up. The spillovers from the above-stated are increased via in-country ICT diffusion (see Figure 30).

Figure 30. Technological progress of nations. Source: Composed by the author based on World Bank report (2008).



The literature has suggested that countries on the path of development are intensive consumers of foreign inputs but do little at the frontier of technological innovation. Therefore, the common trend is that scientific innovation, older and newer technologies are rife in such high-income countries compared with their low-income counterparts. There is no argument that most developing countries exist in this bracket, and therefore are major consumers of foreign inputs. Globalization and better policies do enable such economies to strengthen their technology absorptive capacity and drive technological progress. In many cases, technology spreads to such countries relatively rapidly, but the challenge has been its diffusion within these countries. Yet, a remote example about India, according to the Indian Telecommunications Regulatory Authority, is that mobile telephone penetration in India between 1998 and 2008, rose from below 10% to almost 60% among urban subscribers while for rural subscribers, remained at less than 10% over the same period.

The key distinction between the high-income and low-income economies mostly centres around (1) the macroeconomic environment, (2) financial structure and intermediation (especially innovative activities), (3) basic and advanced technological literacy, and (4) the regulatory environment and technology governance. These factors are the major drivers of technology absorptive capacity for nations according to the World Bank prescription. In this sense, **weak technology absorptive capacity can constrain the technological progress of nations**. The influence of trade, FDI, the external environment and R&D cannot be divorced from the technological progress of nations, neither can governance and policy in the resource allocation scheme.

5.3.2. Estonia's economic transition (pre-study events)

The most important natural resources in Estonia between 1960 and 1988 included (1) oil shale (6425.5 million t.), rock phosphate (167.7 million t., calculated as having 100 percent P_2O_5 content), limestone (292 million t.), clay (64.7 million t.), and sand (2.1 million t.), also quartz sand (3.8 million t.), construction sand (175.3 million t.), gravel sand (28.8 million t.), and deposits of dolomite (493 thousand cubic meters) (BOFIT, 1995).

Historically, the most important sector of the Estonian economy was agriculture, mostly the cultivation of land. In the towns, handicrafts and trade. By the 17th century, manufacturing enterprises began to spring up. The textile industry was one such that emerged in the late 1820s. This was followed in no particular order by the machine, metal, cement and peat industries in the second half of the 19th century. Estonia exported raw materials and semi-manufactured products to the United Kingdom, Germany, Sweden, Finland and the Soviet Union. Kukk (1991) makes the point that Estonia was characterized by a well-developed technical and social infrastructure as well as a strong work ethic among Estonians. The economy was radically transformed after the incorporation of Estonia into the Soviet Union in 1940. The economic annexation though reported as a component of colonial policy was also reported as ideological. By the end of the Soviet period, in the late 1980s, Estonia had become an industrial-agrarian economy. According to BOFIT, during the final years of the Soviet era, industry accounted for approximately 60 per cent of the gross material product (GMP) and 40 per cent of the net material product (NMP) with the share of agriculture being 20 per cent. **Industry is significant as a contributing factor to exposure to technological frontiers** (see Figures 31 and 32). For context, the system of national accounts (SNA), which relates to market economies, emphasized GDP, which essentially looks for the amount of economic activity in an economy. GNP on the other hand, accounted only for the economic activities of citizens, including those outside the borders of a given country. The GNP was based on the material product system (MPS), common in planned economies, which was synonymous with regimes such as the Soviet Union, Cuba and China, where services were not considered value-adding and were excluded from the total net output of a given economy. The SNA was introduced in 2008 and is a statistical framework that provides a comprehensive, consistent and flexible set of macroeconomic accounts for policymaking, analysis and research purposes in market economies (World Bank 2009; Bwanakare, 2019).

Figure 31. Gross material product, Estonia - 1960-1988. Source: Composed by the author based on BOFIT data (1995).

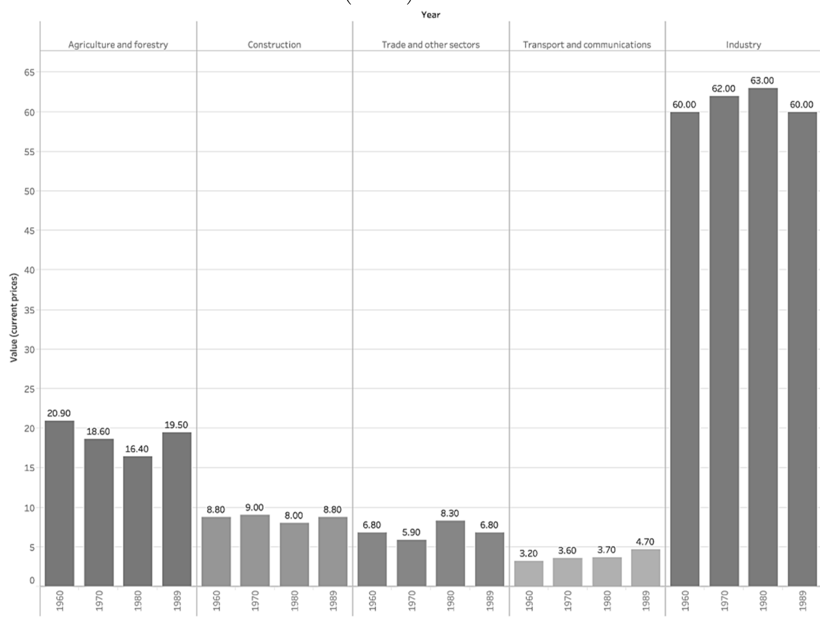
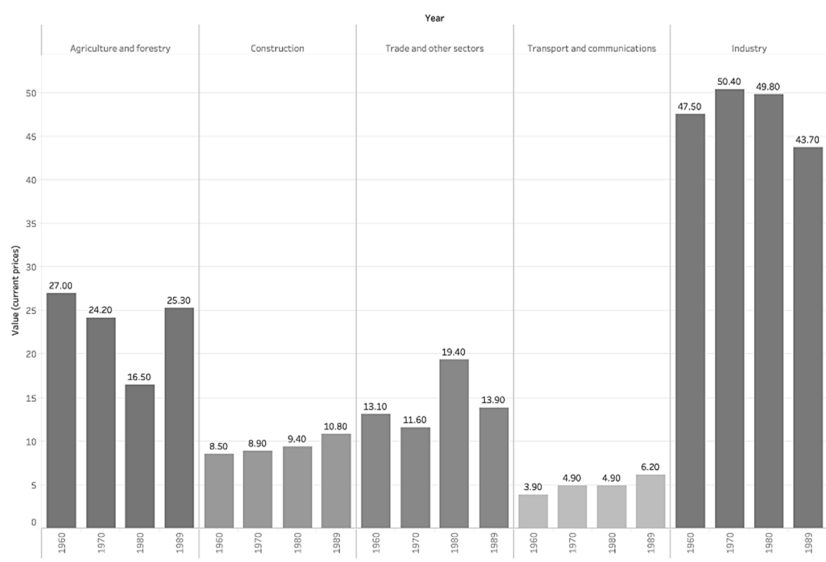


Figure 32. Net material product, Estonia - 1960-1988. Source: Composed by the author based on BOFIT data (1995)



In terms of economic reformation, from the mid-1980s to 1992, the Estonian market was functioning but market signals were not to a great extent considered. The command economy was reformed without any fundamental change in the economic system. From 1992, after the monetary reform, the economy began its transformation from a command to a market-driven economy. The result of the new economic policy was the exposure of the state-owned enterprises to the discipline of the market. This meant the elimination of soft credit, subsidies, and tax breaks, and the introduction of hard budget constraints for state enterprises. It is further reported that the introduction of market signals as behaviour stimuli was only a first step, which was followed by further liberalization (particularly regarding external transactions), land and agricultural reforms and the development of the financial sector. Privatization and the establishment and spread of entrepreneurship were necessary pre-conditions that created the change in the economic environment.

The next steps in transforming the Estonian economy was the introduction of a market-based financial system. This led to the introduction of the currency board arrangement, and the role of Eesti Pank was clearly defined. No entity had the financial authority to interfere in the market to control interest rates or money market operations (see Bennett, 1992; Lainela-Sutela, 1994; Hanke-Jonung-Schuler, 1992; Bennett, 1993; Hansson-Sachs, 1994; Schwarts, 1993; Honahan, 1994; Osband-Villaneuva, 1992; Eesti Pank Quarterly Review and Bulletins, 1993 and 1994; and IMF, 1993). The Transition from a planned to a market economy was crucial in the economic transformation.

5.2.3. The tiger leap project and technology policy (governance) in the Estonian social system

Nelson and Phelps asserted in 1966 that 'education played a positive effect on the speed of ICT diffusion'. Cantwell (1999) also noted that 'technological progress is enforced by a continuous process of learning and is characterized by cumulativeness and irreversibility'.

The Estonian '**Tiger Leap programme'** is considered a major overarching factor in the speed of ICT diffusion in the Estonian social system. The **Estonian Educational and Research Network (EENet)** was created in 1993 as a nationwide scientific and educational computer network to further the ICT cause in Estonia. In February 1996, the Government launched the 'Tiger Leap' programme to modernize education.

Tiger Leap had the slogan 'one computer for every 20 pupils' and helped to provide IT facilities in schools. National programmes were launched massively on network usage and e-government with the goal of attaining internet penetration of more than 70 per cent, according to public records. Internet services were heavily supported from all fronts. By the year 2000, all schools had computers and by 2003, 98 per cent had been connected to the internet. ICTs were integrated into the curriculum as a subject and a tool for teaching other subjects. The fact that Estonia's government became more connected and ICT-literate and integrated e-government practices into existing frameworks, was remarkable. The Prime Minister's office began by opening a platform for public participation in the legislative process online. The most notable of the initiatives that garnered the most attention was the Electronic Cabinet, which allows government ministers to review legislation, make comments and suggestions, and vote online. The Estonian Parliament adopted the '**Principles of the Estonian Information Policy**' as early as

May 1998 as a roadmap for the country's development in ICTs and different programmes were created, focusing on specific areas.

The case of Estonia depicts a unique example of civic participatory culture developed in parallel with and strongly influenced by ICT development. For example, Reinsalu and Winsvold (2008) have looked at ICTs as tools for civic involvement in political affairs in Estonia and confirmed that ICTs have strongly influenced democracy and participation and are much more integrated into Estonia's concept of democracy and political participation. Pruulmann-Vengerfeldt (2007) also extensively covered social development and civic participation in the political agenda. To buttress these positions, the Principles of Estonian Information Policy churned out in 1998 sought to use ICTs to (1) increase the competitiveness of Estonia; (2) reduce division within society; and (3) foster state–individual relationships, as part of efforts towards social re-configuring, which has been argued is not a mutually exclusive component of technological change, in the sense of sociotechnical theory.

In a recent study of innovation in the public sector of Estonia, Parna et al. (2007) asserted that external factors, such as supportive policies, appropriate laws and regulations, competition, and a technology boost, are relatively more important as contributors to innovation success in Estonia than in other countries. This assertion is founded on the basis that public service innovation in Estonia is more advanced than in other countries because it is focused on the issues related to raised service diversity and reduced time spent on service delivery (including waiting times). The study further ascribes the innovation success to, "the small size of the country, as projects are smaller, and therefore less risky to carry out. Also, relatively smaller national wealth (i.e. resources available) together with the advanced infrastructure (telecommunication, electronic banking, ID card, digital signature, etc.)," all account for the transformation.

With a view to leapfrogging the West's technology (Burlamaqui and Kattel, 2016), the influence of political forces in Estonia's digital change cannot be left out. After re-independence, clear ideological machinery existed to change the Soviet legacy; therefore, technology governance, innovation and public policies were churned out massively from the days of Mart Laar, Prime Minister of Estonia at the time. Though it has been argued that it was more a coordinated effort than political direction, this is indeed arguable.

An aspect of technological governance is the digital literacy domain. In this domain, raising digital literacy and e-user skills is the objective. This requires a strategic approach via policy programmes and projects. Some of the programmes and projects in Estonia have included:

- "**Be Included**" programme initiated in 2002 by the Look@World Foundation, extended the network of public internet access points and provided schools with computers, among others.
- As at 2013, the development of the **Estonian ICT Sector Vision 2020** from the Estonian Association of Information Technology and Telecommunications, calling for increased amount of free re-training for ICT specialists, among others.
- The **Estonian Information Society Development Plan 2020** for new programmes and initiatives in the coming years.
- In 2011, the Estonian Government launched a new Competitiveness Strategy "**Estonia 2020**".
- Another political initiative is the Information Society Policy of 1992; which was re-drafted in 2013 as the

Estonian Information Society Strategy 2020 to focus national resources on the digital literacy and supply of ICT practitioners.

- The Estonian Information Technology College was established through a multi-stakeholder partnership, including the Estonian Ministry of Education and Research.
- The **Tiger University Programme** was set up in 2002 to support the development of ICT infrastructure in higher educational institutions.
- Other projects initiated by the Tiger Leap Foundation includes the **ProgeTiger** and **SmartLabs** for kids.
- A national Research and Development Strategy was introduced to foster cooperation among educational institutions in Estonia.
- A number of policy programmes and stakeholder initiatives for digital entrepreneurship. The Estonian Government initiated **Start-Up Estonia** as an innovation hub and incubator.

The evidence suggests that there have been activities for raising digital literacy and e-user skills in Estonia with a strong foundation for improving ICT practice and skills over the years. The initiatives have been massive for both the public and private sectors of the Estonian economy. However, reports of a brain drain due to poor or low remuneration of ICT practitioners have been rife. Therefore, innovation policy, legislative framework and improved technology governance are required to maintain the digital literacy domain.

5.4. Inferences from straw-in-the-wind test

Inference: Innovation policies implemented and technology governance practices could have been influential in fostering economic innovation, but test results do not demonstrate this.

The evidence suggests that the leadership of Estonia played a significant role in the digital transformation in Estonia. These could be inferred from the policies churned out and implemented, as well as governance measures taken to start programmes and projects in furtherance of this endeavour, through cross-party efforts and collective coordination.

The role of technology governance and innovation policy has been considered in several studies with dissenting conclusions. What is important is that, to raise economic growth rates, the production processes must move up the value chain. This means guidance by shaping economic growth processes. Such a move by a government introduces knowledge accumulation, agglomeration, and specialization rents, enabling the provision of high levels of compensation for the production factors employed. The transformation is facilitated by investments in capital equipment, human capital development and technological innovation, providing a conducive business environment and overall enhancing technological frontiers. Therefore, it can be suggested that technology governance and innovation policy were influential in driving economic innovation. What remains yet to be confirmed is whether these were central tenets to the re-formulation of Estonia's economic growth model more explicitly.

Alternative Inference: With a weaker assumption, technology governance and innovation policy may not have been influential in driving economic innovation in Estonia but this is not precluded.

The assumptions of Hypotheses 5 are considered weak in this work because they do not provide sufficient evidence (in the sense of Beach et al., 2013) to weaken the main hypotheses set up (see section 3.4). Therefore, though these pieces of evidence cannot be precluded from the narrative, there is no strong assumption suggesting that these activities lend credence to economic innovation and to economic growth for that matter. At the same time, the weight of evidence submitted in this work in relation to Hypothesis 5 is sufficiently significant to make a point. Hypothesis 5 cannot be dispelled, yet does not provide sufficient explanation for the e-revolution in Estonia.

Summary: These are promising contributions, a **straw-in-the-wind**, which lends weight to $\mathbf{H_1}$ and $\mathbf{H_3}$ but is not in itself a decisive piece of evidence in explaining Estonia's economic growth. The straw-in-the-wind favours $\mathbf{H_1}$ and $\mathbf{H_3}$ but does not confirm them.

In tandem with the above, the evidence provided through the testing of $\mathbf{H_4}$ and $\mathbf{H_5}$ lend weight to the thesis, but do not provide decisive evidence of a causality link with economic innovation or economic growth, based on the tests conducted. Therefore, $\mathbf{H_5}$ cannot be confirmed. While this is the case, in section 6.2, a possible outcome outside of the initial causal sequence framework is introduced

5.5. Chapter summary

In this chapter, the findings from the analysis of evidence in support of the rival hypotheses were presented. The evidence submitted, though overwhelming, lacks the capacity to pass the rigour and robustness tests typically seen with quantitative analyses, yet provides strong support for the main assumptions stated in the dissertation. Considering the data analysed and inferences made, **$\mathbf{H_4}$ was rejected, meanwhile $\mathbf{H_5}$ could not be confirmed**. In the next chapter, all the pieces of evidence are brought together to decide their weighting and capacity to influence the stated outcome.

6. ASSESSING THE INFERENTIAL WEIGHT OF THE EVIDENCE AND DISCUSSION OF THE AUXILIARY OUTCOME

This chapter assesses the inferential weight of evidence and analyses possible auxiliaries in the causal process not included in the initial causal sequence framework (see section 2.7) and the hypothesized mechanism (see section 3.5). In section 6.1, an assessment is made based on the evidence submitted in Chapters 4 and 5, which employed a smoking gun test, hoop test and straw-in-the-wind test to analyse data to establish whether the evidence provided met both the necessary or sufficient standard in the sense of Beach and Pedersen (2013). A weighted decision matrix (Bennett, 2010; Colier, 2011) was developed and engaged as a method of elimination, and decision criteria are used in a doubly decisive test (see section 3.4). Though subjective, the inferences and conclusions assert a degree of confidence in each part of the hypothesized mechanism to address RQs 2 and 3. In section 6.2, a possible alternative outcome, which was not part of the main causal sequence framework, yet could provide valuable inferential leverage, is introduced and assessed. In section 6.3, the causal mechanism and causal process are subjected to further analysis. Estonia's digital plan to accelerated innovation- and technology-led economic growth is analysed. The analysis is a precursor to answering RQ4, and in section 6.4 draws out recommendations concerning innovation governance and management in Estonia from the process-tracing exercise performed.

6.1. Assessing inferential weight of evidence

In the section 6.1, the inferential weight of evidence submitted is assessed using the matrix for assessing the certainty and uniqueness of evidence (Bennett, 2010; Beach and Pedersen, 2013). A doubly decisive test (see section 3.4) is performed by evaluating alternative hypotheses. Bennett (2010), a key proponent and process-tracer, noted that single tests that accomplish robustness and rigor measurements are rare in the social sciences, but this leverage may be achieved by combining multiple tests, which together support one explanation and eliminate others. Consequently, hypothesis n is introduced for the doubly decisive test. Hypothesis n is stated as:

- **H_n**: Selected innovation- and technology-led economic growth factors are significant predictors of Estonia's economic development.

6.1.1. Weighted decision matrix

In line with the proposal by Bennett (2010) and Beach and Pedersen (2013), the following weighted decision matrix is developed specifically for this work (see Figure 33 and Table 30). **The weighting is as follows**: 1= Fail; 2=Pass; 0=unconfirmed

Figure 33. Weighted decision matrix. Source: Composed by the author - inferences based on hypotheses testing.

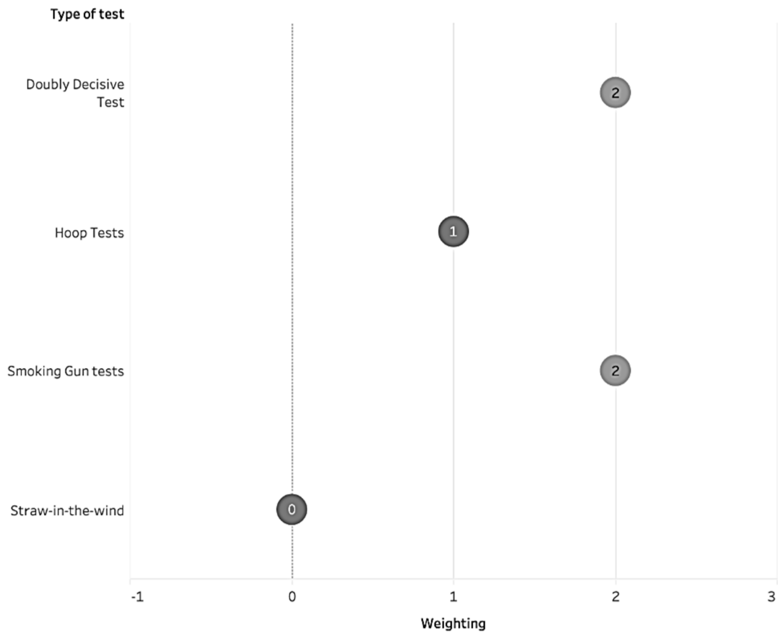


Table 30. Weighted decision table. Source: Composed by the author - inferences based on hypotheses testing.

Type of test	H	Criteria for elimina-tion	Summary Inference from tests	Alternative Inference	Weighting	Conclusion (section 3.4)
Smoking Gun tests	H_1-H_3	Pass	R&D expenditure, number of patent applications are exceptionally unusual; Human capital development, technological innovation are exceptionally unusual; regional innovation capability are exceptionally unusual, they are **smoking guns** that confirms H_1-H_3, weakening the plausibility of H_4-H_5,	A3: R&D expenditure, number of patent applications are interpreted as **somewhat unusual**, suggesting, but hardly confirming the relationship with economic growth.	2	Sufficient for Affirming causal Inference
Hoop Tests	H_4	Fail	With a stronger assumption, this is a Hoop test which fails **H_4**; with a weaker assumption, it is a straw-in-the-wind test which casts doubt on **H_4**.	With a weaker assumption about the influence of the x-road, there is some doubt about the link to economic innovation but does not preclude it.	1	Not Necessary for Affirming causal Inference
Straw-in-the-wind	H_5	Unconfirmed	This is a promising contribution, a **straw-in-the-wind**, which lends weight to **H_1** and **H_3** but is not by itself a decisive piece of evidence in economic growth. The straw-in-the-wind favors **H_1** and **H_3** but does not confirm it.	NA	0	Necessary for Affirming causal Inference

Doubly Decisive Test	Hn	Pass	The combined weight of the Hypotheses 5 - straw-in-wind; Hypothesis 4 eliminated by hoop tests, strongly favor the assumptions that Hypothesis 1-3 may be a smoking gun, providing strong evidence in support of the **Research Problem** -- and answering the **Research Questions** in consequence -	Assumptions of Hypothesis 5 are strong and weaken the strength of Hypothesis 1-3. Hypothesis 4 however Failed and strengthens the assumptions of H_2 and H_3.	2	Sufficient for Affirming causal Inference

Inference: The assumptions of H_1–H_3, suggest a strong relationship between economic growth determinants and the economic development of Estonia.

Alternative Inference: The assumptions of H_4 and H_5 suggest a strong relationship between economic growth determinants and the economic development of Estonia.

Summary for H_n:: The combined weight of H_5 – straw-in-wind; H_4 – eliminated by hoop tests, strongly favour the assumptions that H_1–H_3 may be a smoking gun, providing strong evidence in support of the research problem and answering the RQs (see section 3.4) – that a relationship exists between growth determinants in the innovation- and technology-led economy and the economic development of Estonia.

Summary of Doubly Decisive Test: Four (4) out of Five (5) tests provide inferences based on the evidence submitted, the combined weighting of which support Hypotheses 1–5, suggesting but not confirming that the factors analysed could be growth determinants for the sustained economic development of Estonia and of nations. In the next section, the arguments are further kindled, with the introduction of a secondary possibility into the analyses.

6.2. Auxiliary outcome

In this section, an auxiliary outcome, outside of the main causal sequence framework is introduced and considered. The alternative outcome is considered in relation to the case study. Mahoney (2010:125–31), another proponent and process-tracer, suggested that after the inferences are subjected to weighting based on the tests performed, an iterative process is essential to ensure the best possible outcome in the explaining-outcome process-tracing methodology (see section 3.3). In agreement with Mahoney, a possible outcome outside of the original causal sequence framework is introduced. This alternative outcome is hypothesized as follows:

- **H_6**: The Estonian digital transformation is characterized by "development-driven strategies" rather than by "strategy-driven development".

To test H_6, an interpretive case study method is used to examine the alternative outcome, which could influence the hypothesized mechanism, causal process and causal sequence framework, and which may further support the causal importance of the innovation- and technology-led economic growth determinants analysed.

The key issue in Estonia's economic development strategy has been technological innovation and human capital development (see sections 4.4 and 4.5). In Estonia, digital inclusion and e-skills issues have been on the Estonian policy agenda continuously since the late 1990s into the early 2000s. The path to the new growth model requires developing an innovative country; that is, building a national innovation system, improving innovation capacity (source innovation, integration innovation, re-innovation, strategic high-tech R&D), cultivating creative talent and improving the innovation environment in general. These also include an export-oriented policy and investment-led strategies for industrialization and urbanization.

Evidence points to national digital initiatives since 2000; however, the records on Estonia's digital progress were captured against global benchmarks on its ascension to the EU in 2004. Could the joining of the EU, which was predominantly through political effort, be the chief causal mechanism not closely considered? Some commentators have made the point strongly that the many strategic documents for digital transformation have followed European structural funding opportunities rather than a careful, calculated response to domestic challenges and processes. Is Estonia's digital success a product of national effort, a couple of policies, programmes and initiatives?

This work argues in favour of a strategy-driven development approach. According to evolutionary theorists such as Darwin (1809–1882), Lamark (1744–1829), and Wallace (1823–1913), society evolves naturally. However, the primary issue has been in what direction? If no strategic efforts were laid towards the end goal of a digital nation, it is unlikely Estonia, now a digital nation, would have made the strides it has, or would it? Another line of thinking which contradicts the stance of evolutionary thinking is that neighbouring countries, such as Latvia and Lithuania, which began from the same point as Estonia, have not attained the same digital feat. With approximately similar numbers in terms of population and many other country characteristics, they are still lagging. Here comes the bigger dilemma: the argument has been made that unlike other countries, such as the United Kingdom, Estonia never had a central office for digital transformation, despite its mention in "*Estonia's Roadmap to the Information Society*" in 1994. It is also argued that no national formally empowered official was named for digital enablement, until more recently, in 2018 thereabouts, when IT was added to a ministerial portfolio. Could the processes leading to the digital transformation have been ad hoc and informal? How is it then that the Estonian Information Society Strategy introduced in 2013, was approved by the Estonian Government in November of 2006, just to mention one example?

Economies and for that matter digital societies (see Glossary) do not just happen. Otherwise, all nations with or without a digital transformation would have a digital success story to share. Technological change (see section 2.1) and its associated progress (Dosi et al., 1988) must be steered in a direction: in the right direction. Technological inertia, which is an external force, has the capacity to disrupt, but the technological paradigm shift is internal. Leadership, technology governance and innovation policies are responsible for this drive in the digital transformation. Some of these steps may be explicit, others may be tacit. It is posited that, national digital transformation is a calculated effort, and therefore no happenstance. Further, education and learning are at the heart of building the necessary foundation for the digital inclusion stage of the transformation process. This encourages the cumulativeness and irreversibility of the digital transformation process, together with enhancing technological frontiers. Therefore, Estonia's case cannot be different, given the evidence as identified and put forward in this work. It is simply not feasible to harness knowledge accumulated over time and processed for insights in an ongoing effort, powered by highly skilled human capacity and technological innovation, without a strategy-driven development arrangement. In section 6.3, a digital plan is outlined in support of the strategy-driven development agenda argument as asserted in this section.

Inference: The assumptions of H_6 suggest that Estonia's digital success story is a product of a development-driven approach rather than strategy-driven coordinated policy or bundle of programmes.

Alternative Inference: With a weaker assumption, Estonia's accelerated digital transformation was based on a digital initiative arising from documented foundational policy and strategy implementation over the long term.

Summary: Based on the argument so far, these are promising contributions that a “strategy-driven development” approach was adopted to arrive at the digital state and digital citizen status: a **straw-in-the-wind**, which lends weight to **the original outcome** but is not by itself a decisive piece of evidence in the economic trajectory of Estonia. The Alternative Inference contains stronger assumptions that further the author’s arguments. The straw-in-the-wind favours $\mathbf{H_6}$ but does not confirm it. In view of the above, this work adopts a “strategy-driven development” path over the “development-driven strategies.” This could be taken for semantics but refers to the strong presence of documented foundational policy and strategy. In effect, the distinction may be challenging to characterize yet is outlined in section 6.3.

6.3. Estonia’s digital plan for accelerated economic growth

In this section, the causal mechanisms in the causal sequence framework, the causal process and auxiliary outcome, are subjected to a holistic review and analysis. The analysis sought to identify and harmonize the implications of the process-tracing results for the Estonian economy as a whole. A Digital Plan purportedly pursued in Estonia through a strategy-driven development agenda is suggested at the end of the analysis.

Generally, the “digital economy” is seen as the future of growth, where the criteria for sustainable value and an inclusive economy is a new economic growth model driven by technological disruption being experienced in what is known as the *Fourth Industrial Revolution* in contemporary times. But what is the digital economy of Estonia? Indeed, there are no agreed definitions of the digital sector, products, or transactions, let alone the digital economy (Ducharme et al., IMF, 2018). The challenge here is that assessing the impact of online platforms, and activities that owe their existence to such platforms, is not sufficient to explain the digital economy in relation to the Estonian economy; for example, because activities that use digitized data are part of the digital economy, and especially in Estonia, that is practically every economic and non-economic activity combined, where the digital economy encompasses an enormous diffuse part of the entire Estonian economy.

Though fast developing, platform-enabled services – such as the sharing economy, whose main components are peer-to-peer short-term property rentals and peer-to-peer labour services (e.g. Uber) – are barely covered in economic growth calculations and analysis. Aspects of the digital sector, such as collaborative finance (e.g. peer-to-peer lending), which are also part of the sharing economy, all the way to businesses in the gig economy, such as crowdsourcing platforms (e.g. freelancers and Upwork) among others, are inadequately covered or not taken into consideration at all. Online platforms (e.g. Google, Facebook, YouTube, Alibaba, etc.) and their products are incompletely considered or not at all. The current classifications of the digital economy cannot keep up with the recent growth of digital services and products. The World Economic Forum has predicted that over 60% of global GDP will be digitized; over 70% of new value created in the economy will be based on digitally enabled platforms and industries (WEF, 2015). That begs the question of which economic growth factors will drive this transformation in changing the economic trajectory and industrial mix? Which ones have the capacity to transform the economic growth model through technology and innovation?

Recent studies by not only the WEF but also by Deloitte suggest that some fundamental areas of digital transformation are crucial to the digital economy, such as:

- **Future of work**: increased connectivity and flexibility so that people can work from anywhere.
- **Customer experience**: satisfying the customers' desire for engagement with brands through experiences that are seamless, omnichannel, direct, contextual, and personalized.
- **Digital supply networks**: new intelligent digital networks will be created that will fundamentally change the way commerce is managed, shared, and deployed.
- **Internet of Things**: an age of connectedness, where people, businesses, devices, and processes are all connected in a seamless fashion.

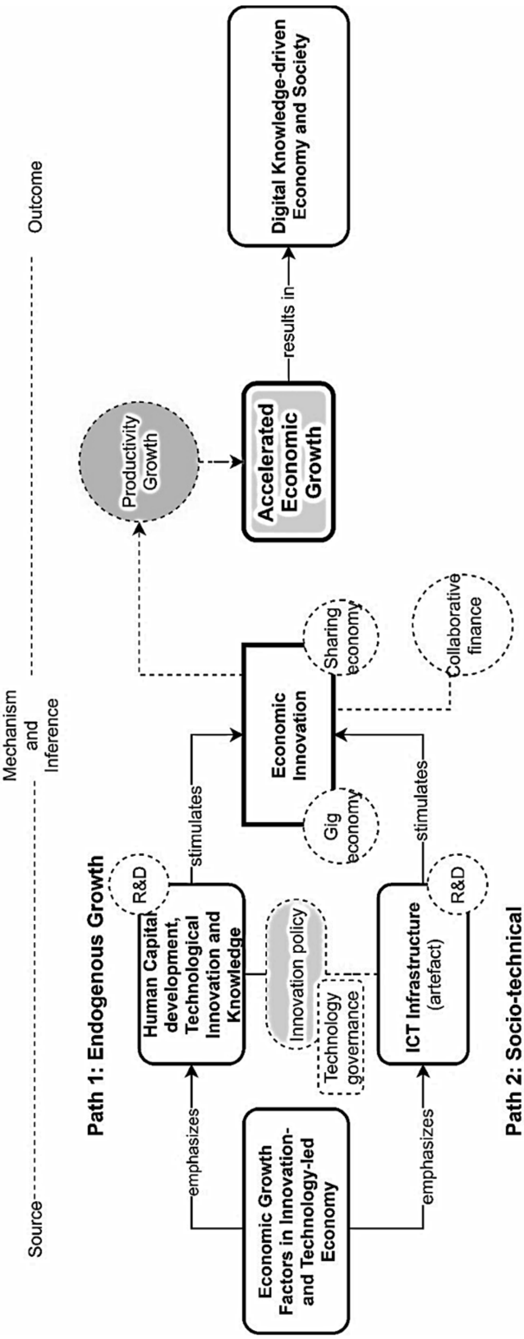
In exploring the economic trajectory of Estonia since 2000, two theories are subjected to analyses, connecting innovation- and technology-led economic growth determinants and economic innovation to the new areas of digital transformation and the digital economy (see Figure 34 – the dashed lines show indirect relationships). This further iterative step introduces supplementary possibilities into the process-tracing exercise. It was observed in section 2.2 that factors of economic growth are inputs into the economic growth process, where the economy and society remain important elements in this process. The outputs are economic growth and economic development. During the evolution of economic growth and development models (see section 2.1), each of the theoretical waves saw a focus on a group of economic growth factors, which were considered determinants, based on the economy or set of economies studied. Mahoney (2010) suggested careful description as the foundation of process tracing. The causal mechanism is described in this vein. When the iteration should end is left to the researcher, research questions and problem at hand.

6.3.1. Causal mechanisms: linking growth determinants in the innovation- and technology-led economy to economic innovation; economic growth and development in Estonia

The analyses so far demonstrated that, in general, the disputed notion of the digital economy is more likely in conditions of high levels of economic development. The question remains: What was the causal process through which these relatively abstract and distant concepts and causal mechanisms operated leading to the digital economy? This subsection probes the causal pathways or mechanisms linking the observed patterns in this study to the digital economy, and giving the findings above greater plausibility, while also deepening our understanding of the process for the digital economy.

There are many different mechanisms with distinct observable implications that possibly show how economic development is sustained over the long term through increased productivity and growth. The initial causal sequence framework depicted a simple causal trace to economic growth (see section 2.7). Based on the study and theoretical inquiry, however, two pathways are analysed culminating in a revised causal sequence framework (see Figure 34).

Figure 34. Causal Mechanisms, the causal process and auxiliary outcome
Source: Composed by the author.



6.3.2. Path 1: endogenous growth as causal mechanism

The endogenous growth perspective emanated from the works of Solow (1956) (see section 2.1). Solow argued that productivity growth could not be influenced by anything in the rest of the economy beyond the traditional views then held by economists in the 1960s; these views suggested that some factors were exogenous to economic growth. Romer from the 1980s revolutionized the conventional view of mainstream thinking about economic growth in his seminal works. Romer emphasized that anything that affects the efforts of researchers and entrepreneurs such as tax policy, basic research funding, education, for example, could potentially influence the long-run prospects of an economy. He argued that in endogenous growth theory, technological advancement was the result of these efforts. He called this the "economics of ideas". This was captured adequately in his seminal work, which earned him the Nobel Prize in Economics.

Therefore, we turn to the very basic principles of Romer's (1986) endogenous growth model, which should provide an explanation of the causal mechanisms considered in this work and the expected outcomes as discussed.

1. **Ideas** – designs and blueprints for doing something or making something: Romer argued that this was non-rival, as in, different from nearly every other good. In classical economics, standard goods are rival in the sense that as demand increases for a particular good or service, supply for those particular goods falls. This rivalry underlies scarcity, which is at the heart of the economics literature, which also gives rise to the fundamental theorems of welfare economics.
2. **Ideas are non-rival** – Here Romer (1986) asserted that unlike traditional goods, ideas are not depleted by use, and it is

> technologically feasible for any number of people to use ideas simultaneously once invented.

Now, how does this concept of rivalry explain innovation- and technology-led economic growth? Consider a situation where the Estonian government as a manufacturer of computer chips wants to double production from a state manufacturing factory. One way to do this would be to build an equivalent factory and populate it with workers, materials and so forth. This will give rise to increasing returns to scale; satisfying the "standard replication argument", which is considered a fundamental justification for constant returns to scale in production. Romer's work stressed that the nonrivalry of ideas is an integral part of the replication argument. The government of Estonia would not need to reinvent the idea for a new computer chip each time a new one is built. Instead, the same idea can be used in a new factory, or in other countries, say in Latvia or Lithuania. In this case, there will be constant returns to scale in the rival inputs (the factory, works and materials), and therefore increasing returns to the rival inputs and ideas when taken together, the quality and quantity of ideas doubled will double total production. The point being that in endogenous growth theory, building macroeconomic models out of microeconomic foundations is crucial. Additionally, households maximizing utility subject to budgetary constraints and firms maximizing profits are the main assumptions. Of importance to endogenous growth thinking is the production of new technologies and human capital development.

The analysis of data (see Chapter 4) indicated that both explanatory (input) variables R&D expenditure and number of patent applications were not innovation- and technology-led economic growth determinants in explaining economic growth domestically in Estonia, but R&D expenditure was significant in accounting for economic convergence and growth in the EU region.

This means, though not reflected locally, that R&D was significant in the converging levels of income differences in the EU region and by extension, levelling economic development in the region. R&D expenditure is an innovation- and technology-led economic growth determinant, which predicted regional economic growth but not economic growth in Estonia since 2000. **Therefore, in explaining the causal process, the combination of R&D expenditure, human capital development and technological innovation supports endogenous growth in this sense as determining factors**. The confluence of new theories and new data is making the subject of endogenous growth theory an exciting one in economics literature. It will be good to employ more qualitative methods in future probes to bring out some underlying factors, not captured in the quantitative analyses in this dissertation, such as a qualitative review of R&D activities in Estonia since 2000, and why the number of patent applications is relatively lower compared to other countries in the EU region.

6.3.3. Path 2: socio-technical theory as a causal mechanism

First, what is socio-technical theory or thinking? There are several ways of looking at the concept: (1) It can be considered as a way of understanding the relationship between technology, individuals or a social system made up of individuals, organizations and other units of analysis in the socio-technical system (Rogers, 2003). Components include hardware, software, the social system, leadership and the political setting, and policy and governance as subsets of the socio-technical system. (2) Another way of looking at socio-technical thinking is to understand social aspects resulting from interactions between a social system and technical aspects such as machines and technologies in that matrix.

Socio-technical theory emphasizes technological infrastructure as part of the world and its dynamics. For example, Latour (1987) referred to immutable mobiles as artefacts (or the technical sub-system). These artefacts, or ICT infrastructure in his view, when diffused in the social system are responsible for irreversibility, embeddedness, and path dependence in social systems. Rip and Kemp (1998) considered socio-technical systems and concluded that, when technologies are diffused in a social system, they become embedded in a seamless interdependent web between the social and technical, endogenizing the technology. In essence, technological change is triggered by technological infrastructure, according to socio-technical theory.

Socio-technical theory emphasizes the presence of two sub-systems:

- Technical sub-system
- Social sub-system

According to Hughes (1983, 1987), Maytntz and Hughes (1988), Schmid and Werle (1992), Callon (1986a, b), Law (1987), Law and Callon (1988), Mangematin and Callon (1995), Latour (1996), Rip and Kemp, (1998) and Watson (2004), the technical sub-system is often identified using the process of the accumulation of knowledge in the social system. On the other hand, the social sub-system goes beyond the technical aspects, into other aspects which are considered to include other factors (such as culture) in the social system. In this, every facet in the socio-technical system plays a role in the accumulation of knowledge through ICT instruments (typically information systems) and infrastructure. These are configurations that work – are tangible arrangements, machines, and so on, that are technical in nature and considered irreversible by their immutability. The social sub-system, as a unit of analysis includes individuals, organizations and other units that create knowledge through various interaction mechanisms in the technical sub-system.

The importance of the x-road (see section 5.1) in the development of Estonia cannot be underplayed, in that countries that have transformed their economies into information societies have ridden on the back of ICTs and the case of Estonia is no different. The x-road infrastructure resolved a major challenge in the information systems of Estonia, by serving as an integrator in the information systems, which was previously missing. The place of technology governance and innovation policy in the socio-technical system in Estonia has also been considered in this study. The x-road became so successful, it was exported to neighbouring and far away countries as a blueprint for gluing fragmented country-level information systems together.

How is socio-technical thinking linked to the economic growth of Estonia? First, it is necessary to get a sense of the benchmark for successful innovation- and technology-led economies. In the innovation- and technology-led economic growth model, economic development is linked to how each country leverages technology for development across all sectors of the economy and not only related to the traditional sectors of the economy. The socio-technical perspective makes for a holistic measurement of the progress of innovation across a country – more like a **Balanced Technological Scorecard**. A balanced technological scorecard in this dissertation can be specified as **a holistic measurement of technological change, which includes an account of both technical and social subsystem components in the socio-technical system**. A framework that measures the technical subsystem component is the Networked Readiness Index (see Appendix 5). Having ranked between 18th and 26th place between 2000 and 2015, Estonia's progress on this benchmark seems appreciable.

How do the causal mechanisms explain technological change in the sense of socio-technical theory? The indicators of innovation, competitiveness and ICT include individual ICT usage benchmarks, business usage benchmarks, government usage of ICT, among others on various global indicators, including the NRI. Estonia has consistently been a high performer on these indicators, which together satisfy the measurement of these on the International Telecommunications Union ICT framework dimensions (see Glossary), including cultural, technological, economic, spatial, and occupational dimensions. In the ITU *Measuring the Information Society* report (2015), Estonia ranked 20th place out of 167 countries globally ranked, compared to ranking 25th in 2010 on these dimensions. In the hoop test of ICT infrastructure, it was hypothesized that ICT infrastructure had a significant impact on economic innovation. However, based on the data analysed, the hypothesis was failed (see Section 5.1). Considering that socio-technical theory emphasizes ICT infrastructure as the starting point in the technological advancement process and digital transformation, **it can be suggested that Estonia's main ICT infrastructure, in this sense the x-road infrastructure, satisfies the assertions of the socio-technical theory perspective.** The x-road provided a platform for the exploration of technical mechanisms/processes, which allowed for economic transition and digital transformation. This laid the ground for economic innovation as an input into accelerated economic growth and economic development in Estonia. Bell and Pavitt (1993) and Evenson and Westphal (1995) observed that technology plays a central role in socio-economic development and that change in technology is thus an essential ingredient of development strategies. Geels (2004) observed that when technology is applied in a social system, societal functions are fulfilled. In the view of Geels (2002) and Rip and Kemp (1998), the interlocking of the subsystems – technical and social – creates a web composed of ICT infrastructure, user practices and application domains, culture and symbolic meanings, technological and scientific knowledge, sectoral and industrial networks and strategic games (e.g. financial networks, supplier user groups, producer networks, societal groups, public authorities and research networks).

6.3.4. Estonia's digital plan for accelerated economic growth

Now the digital plan behind the Estonian digital transformation is presented graphically (see Figure 35). This **Digital Plan for Accelerated Economic Growth** (also known as the Digital Plan) supports the argument that Estonia's digital success story was carved on the back of a strategy-driven development approach to digital success over the long term and indeed a product of national effort, and a couple of policies, programmes and initiatives, steered in the right direction (see section 6.2). The digital plan outlines how digital initiatives contributed to the digital transformation in Estonia.

The digital plan is divided into four main phases, also known as **digital phases**. Each of these phases represent a key building block with similarly focused initiatives in the digital plan, some of which overlap:

- **Phase 1: Digital Foundation** – this phase emphasizes a foundational building block where human capital development (lifelong acquisition of digital skills, digital literacy) and investment in ICT across government agencies and the private sector aims to compete successfully both within the country and outside; good governance through digital technologies, transforming into digital government were promoted as a requirement for a transition to a digital inclusion phase.
- **Phase 2: Digital Inclusion** – in this phase, the use of digital technologies as a tool to bring better quality of life and equal access to public services for all members of the

Estonia social system was the focus; thereby, creating a knowledge-driven digital society.

- **Phase 3: Digital Transformation** – in the digital transformation phase, building trust and confidence in the use of digital technology was the focus, while boosting the economy with digital technologies.
- **Phase 4: Global Digital Leadership** – significantly enhancing overall ICT readiness as assessed by global indices.

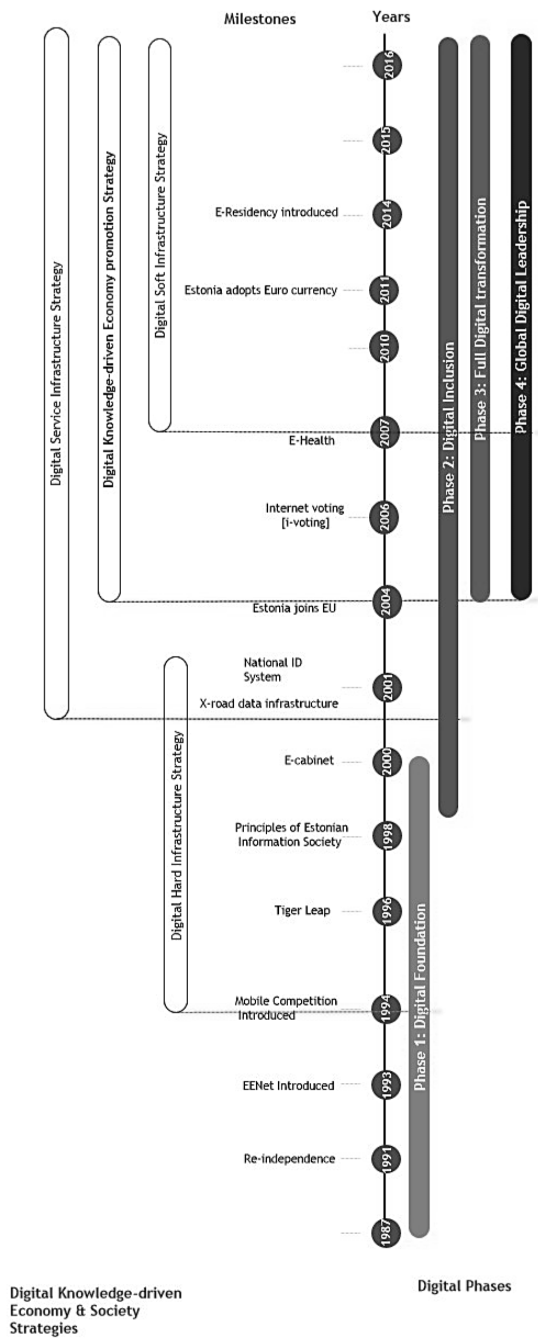
Aside from Phase 1, where the focus was on education and learning as well as policy, the remaining phases were all geared towards sustained and continued digital developments. The key ICT infrastructure (x-road and the ID card system) were introduced to begin the Digital Inclusion phase. The country at the time of this study pursues Global Digital Leadership, with the introduction of e-residency and an Artificial Intelligence strategy as captured in more recent documents in 2020, such as the *Enterprise Estonia e-Estonia Guide 2020.*

To conclude, four key strategies are proposed to have been deployed as sub-strategies under a Digital Knowledge-driven Economy and Society Strategy:

- Digital hard infrastructure strategy;
- Digital service infrastructure strategy;
- Digital soft infrastructure strategy; and
- Digital knowledge-driven economy promotion strategy.

The hard infrastructure refers to digital infrastructure which covers both fixed and mobile infrastructure, and reliable networks that have enough capacity, coverage and suitable pricing to further the digital transformation. **Service infrastructure** refers to infrastructure that enabled service innovations, such as a single access platform for both the government of Estonia and the private sector. **Soft infrastructure** refers to the provision of verification systems to identify individuals and guarantee secure and trusted digital transactions. This also includes standards, laws and regulations. Soft infrastructure also emphasizes social capital (or trust). **Digital Knowledge-driven Economy Promotion Strategy** involves the accelerated development of a vibrant digital business ecosystem that supports small and medium-sized enterprises, entrepreneurs, and technological innovation, as well as capacity building avenues. Meanwhile, society becomes a knowledge society (*Knowledge-based Estonia*) with the creation of a digital society. These are depicted in Figure 35 showing timelines, milestones, and key initiatives to further these strategies.

Figure 35. Estonia's digital plan for accelerated economic growth. Source: Composed by the author.



6.3.5. The development of practical recommendations

The explaining-outcome process-tracing methodology (see section 3.3) selected to answer the RP in this work allowed an in-depth analysis of the case with a view to crafting a minimally sufficient explanation about the mechanisms of sustained economic growth and high levels of productivity in Estonia between 2000 and 2015. The explaining-outcome process-tracing methodology combined with a case study research design (see section 3.4), provided the needed arsenal to initiate actions and processes in conducting the study, which were used to search for evidence to answer the RQs and by extension the RP.

In accounting for a minimally sufficient explanation, the most important facets of the outcome of innovation- and technology-led economic growth and development were considered. These included analysing the impact of innovation- and technology-led economic growth factors as inputs into the innovation- and technology-led economic growth and development model (see section 2.2 and 2.3), such that productivity and economic innovation were intervening concepts in the model with the outcome of economic development as outputs. The causal sequence framework and causal process were depicted in the Conceptual Model of Innovation- and Technology-led Developments (see section 2.7), which provided the key terms and constructs to guide the extraction and interpretation of meaning and context.

To draw out an explanation of the outcome, an interpretivist philosophy (see section 3.1) was adopted so that meanings, human interests, and elements of the study could be subjected to interpretation such that a social reality could be constructed based on the case studied.

An abductive path (see section 3.3) was chosen in operationalizing the thesis in this work. In abducting a plausible explanation from the process-tracing exercise, an iterative research strategy was employed to describe events, causal pathways, causal mechanisms and to convert historical narratives of Estonia into causal inferences and explanations. Doing this made it possible to establish how the outcome of economic development in Estonia was produced.

In operationalizing the research methodology with the Estonian case to arrive at an explanation of the outcome of economic development, the causal sequence framework, the hypothesized mechanism, alternative choice and counterfactual outcomes were leveraged to gather and sift evidence in support of both rival and primary hypotheses. The research strategy was such that growth factors clearly related to the outcome of economic growth and development, which were simple in nature and considered testable, were employed before more complex explanations.

From the study it became clear that the Estonian economy was ripe for the digital revolution that occurred with an economy that was shifting from a planned to a market-based economy (see section 4.2); its leaders were ready to nurture technology and provide the needed ICT infrastructure, policies, frameworks, implementation plans and programmes (see section 5.2), and above all, it had a technologically-ready population (see section 4.4) as well as a regional innovation endowment that could be taken advantage of (see section 4.7). The outcome of accelerated innovation- and technology-led economic growth and development as posited in this thesis, can be accounted for by the Digital Plan for Accelerated Economic Growth outlined in this section. The Digital Plan summarizes events of the case studied, converting historical narratives into causal inferences and explanations of the process leading to the outcome.

In reviewing the causal process leading to the outcome of economic development (see section 6.3), a number of concepts (including the digital society, digital economy and strategy-driven development) were introduced with the expectation that these could influence the causal inferences made and explanations crafted in the study. While these turned out to be straws-in-the-wind and not wielding any inferential leverage based on the methodology employed in the work, they wielded strong explanatory influences, which were leveraged in developing the Digital Plan.

The core concepts which emanated from the process-tracing exercise were the digital strategy and plans, digital economy and digital knowledge-driven economy and society.
Showing that digital plans and strategies, innovation policies, ICT infrastructure, technological innovation (triggered by increased R&D expenditure, reflected in the number of patent applications), human capital development in readiness for increased domestic technology absorptive capacity and regional innovation advantages are important in the innovation- and technology-led economy for developing a digital society.

In this Digital Plan, the technical systems (such as the compulsory national identification cards and the database infrastructure x-road) in the Estonian socio-technical system were highlighted. Endogenous growth factors such as R&D activities, technological innovation, and human capital development, which were process-traced, were equally highlighted. While the findings show that R&D expenditure was significant only in explaining economic development in the European region, it was suggested that a well-developed and sustained human capital base ahead of the study period and the Estonian policy framework (e.g. Principles of Estonian Information Policy, 1998) and programmes (e.g. Estonian

Educational and Research Network, 1993; and Tiger Leap Program in 1996) could be linked to innovation- and technology-led economic growth and development.

The Digital Plan, which provides a minimally sufficient explanation, harmonizes the causal process and inferences abducted from analysing the data into a strategic development resource package that could be extrapolated for use in other countries. Given this fore knowledge, a number of practical recommendations emanating from the entire exercise were developed which are presented in section 6.4.

6.4. Recommendations concerning innovation governance and technology management

In this section, some recommendations concerning innovation governance and technology management in Estonia are outlined, towards providing an answer to RQ4. It must be emphasized that these recommendations are not only for Estonia. While based on the Estonian experience, they could be extrapolated for use in other countries.

RQ4: What recommendations concerning innovation governance and technology management in Estonia can be drawn from the process-tracing exercise?

The World Bank in a 2016 report noted that since the 1950s, there has been rapid economic growth which allowed a significant number of countries to reach middle income status, yet very few have made the additional leap needed to become high income economies. In an earlier report in 2012, the World Bank observed that many developing countries have been caught in what has been called the "middle-income trap", with stable, low growth economic equilibria where talent is misallocated, and technological innovation stagnates (World Bank Report, 2012).

Estonia escaped this "middle-income trap" after its re-independence in 1991, (more specifically from the year 2000) to improve economic growth by shifting the economy from an industry-based economy (where manufacturing accounted for a huge part of the country's GDP) to one that is high-tech driven and able to compete with more advanced economies in the high-value-added market (Schwab 2016). Estonia is an example of an economy transformed over two decades, largely based on foreign trade and FDI (Lumiste, et al., 2008; Kattel, 2018). The EU integration process, Estonia's membership, and cooperation with international organizations such as the World Bank and IMF have all played a role in the transformation process. There are institutional and structural changes as well as infrastructural changes which contributed greatly to the transition from a planned economy to an innovation- and technology-led economy.

6.4.1. Deploying digital plans, strategies and policies

Digital Plans and Strategies: Developing digital plans and strategies is a crucial aspect of innovation governance and management. Developing dedicated innovation policies and governance structures for the digital economy to thrive remains high on the innovation governance and management list. The World Bank (2010) describes the role of government in promoting technological innovation as that of a gardener, supporting innovators by: providing appropriate financial and other measures (watering the plants); removing regulatory, institutional, or competitive obstacles to innovation (removing the weeds and pests); and strengthening the knowledge base through investment in education and research (fertilizing the soil). The following are important and necessary ingredients for an innovation- and technology-led economy to thrive.

- Creating a dedicated ministry for the digital economy; ICT or simply, technology goes a long way to guide the digital transformation in the right direction. For example, both Malaysia and Singapore have ministries dedicated to the digital transformation and have ranked highly on many global indices. It is equally important to place such ministerial portfolios right under the direct leadership of a prime minister or head of government as the case may be. In order to be able to fully deploy digital strategies, digital initiatives have to be driven from the top, through leaders who understand that the government has to be transformed into a digital government; the workforce needs to be developed for the digital transformation; country-wide high-capacity digital infrastructure is needed and also that building trust is an essential component of the digital plan.
- The next step, following the establishment of a dedicated ministry and leadership, is the use of ICT in government administration and services. Enabling the exchange and utilization of data electronically between ministries and agencies of government means faster lead times and greater efficiency in government operations.

Innovation Policy: Alongside all the above steps, a policy framework with the aim of ensuring the establishment of an ICT infrastructure and to foster universal access to the internet for all citizens, while improving security standards and procedures, cannot be left out. These collectively increase economic and social prosperity through digitalization, and places a country at the digital forefront within its economic region and globally.

While in the case of Estonia, a ministry was not dedicated to ICT early on after re-independence, leadership through the then prime minister's office played that role. As a result, several policies and programmes were deployed as part of the digital foundation phase of Estonia's development.

6.4.2. Setting up ICT infrastructure

Some commentators have observed that the foundation of a digital economy is the ICT infrastructure (see section 2.6). A stronger ICT infrastructure means greater investment in economic development. For this, Wehr and Kessler (2017) suggested focusing on the following:

- Universal internet access with good internet speed
- Development of smart infrastructure sharing models
- Implementing a robust regulatory framework
- Building a state-of-the-art, world-class data centre and facility for cloud-based services
- Ensuring reliable and good capacity for international connectivity

In their view, once these key areas are implemented, there will be greater technological readiness, more people using the internet, access to the latest technologies, quality overall infrastructure, mobile broadband subscriptions and connectivity, which will eliminate barriers to FDI, including investments in the digital economy.

Mobile broadband is an important part of the Digital Plan as an important means to bridge the technology divide, especially between urban and rural areas. In Estonia's case, mobile competition was introduced in 1994, allowing for fairly good mobile penetration levels. With the uptake of fifth generation (5G) technologies, policies are further required to streamline the mobile and telephony sectors in Estonia.

6.4.3. R&D expenditure, number of patent applications and technological innovation

According to Wie et al. (2017), technological innovation can take the form of commercial secrets or patents, or it can be about improving business processes and models, in addition to inventing new products or services. Technological innovation can also take place outside the commercial space, such as in the cultural sphere. The source of growth in technological innovation is R&D investment, which is a key input for patents (see section 2.5).

In this work, it was found that R&D expenditure and number of patent applications were not significant in Estonia's economic development. It was also found that the number of patent applications was not significant in the converging economic development in the EU region. While this should suggest low technological innovation for Estonia, special attention needs to be given to the motivation behind patent applications overall. Patents are no longer straightforward methods for protecting technological innovations but have become commercial tools. It has been suggested that strong patent protection cannot be associated with increased R&D expenditure, where the motivations for the patent are administrative and strategic, both of which reduce the innovation incentive effect of the patent system. While this work has not focused on specifically studying the relationship between R&D expenditure and number of patent applications, the following recommendations will be useful for enterprises, business, and individuals.

- Enterprises should strive to achieve balance between patent quantity and quality and to gradually establish a high-quality business growth model. Studies have shown that patent quantity and quality management revolve around the goal of “quantity first then quality”. While the number of patent applications in Estonia is generally low relative to other countries in the EU region, to upgrade a country’s patent profile, high-end inventions are needed through increased R&D expenditure. Added to this is the need for a more rational orientation for a national patent policy.
- In this same vein, enhancing R&D capability in both the public and private sectors have been proven in many studies to promote number of patent applications received at the international patent office.
- Another area worth noting to promote technological innovation is developing ICT entrepreneurs in order to expand international market reach. This will increase ICT-related employment in industries which utilize ICT in their production process and services, and increase the value of the e-commerce market and the economic value of the ICT-based manufacturing industries.

In measuring the innovation performance of countries, typically, the enterprises described in the survey show the main technological (process, product) innovations. Innovations introduced during the last three years but not earlier are subjected to review and analysis. In Estonia’s case, the technological innovations are developed by individuals who represent the enterprise itself (referred to as intramural innovations). Innovations developed by other enterprises or institutions in cooperation are referred to as extramural innovation. During the 2004–2006 innovation survey, it was reported that 37% of Estonian small and medium enterprises (SMEs) developed intramural innovations, noticeably higher than the EU average of 30% of SMEs. For extramural innovations, about 18% of Estonian enterprises were even more successful in innovation cooperation, also twice more than the EU average. This induced a relatively high score on the EIS Scoreboard. What requires attention and could serve also as reference for other countries on the innovation journey are the following.

- Increasing the overall innovation performance of the country through intramural innovation activities, which attracts FDI for innovation cooperation, and therefore higher scores on the EIS and other indices.
- Reducing copy-making of innovations and encouraging new products and process innovations by enterprises. These include new-to-enterprise market (e.g. innovations already available in other markets) and not only new to enterprises (such as innovations already available in the enterprise market from competitors). Estonia has also been in the latter group for a long time.

6.4.4. Building human capacity

A key input and determinant of human capital development, particularly in economies looking to move toward upper middle-income status, is access to quality education. Education is known to equip a national workforce with the skills, knowledge, and creativity to compete in the knowledge-based global economy. While basic numeracy and literacy are starting points, in the innovation- and technology-led economy, specialized skills, training and educational institutions are needed to take advantage of opportunities in the economy.

- **Developing digital literacy**: In the 2016 report of the World Bank, a number of pointers have been highlighted, which could be of use to this work:
    - Taking advantage of digital technologies to promote inclusion, efficiency, and innovation
    - Exposing children to basic ICT and coding concepts at an early age, which could be achieved through the public education system or outside programmes, like coding academies to prepare young people for the opportunities and challenges of the digital workforce.
- **Research universities**: the quality of universities, in terms of their ability to conduct R&D activities, is another important aspect to consider in order to drive innovation- and technology-led economies. Increasing research funding to such universities is equally important to ensure continued R&D activities. While R&D activities are important, these should not happen in isolation. Ensuring a strong linkage and consistent interaction with industry to provide feedback on the knowledge, skills and technological innovations needed to drive the national economy cannot be left out.
- **Innovative and entrepreneurial thinking**: Education systems should encourage students to think critically, pursue innovative ideas and become entrepreneurial. The importance of educational systems that foster technological innovation is key in the innovation- and technology-led economy. Educational programmes that integrate design thinking – an approach that encourages a process of "matching people's needs with what is technologically feasible and what a viable business strategy can convert into

customer value and market opportunity" – should be included in curricula.

For Estonia, according to the EIS, the education attainment level represented by the share of the population with tertiary education is contrasted by a lag in lifelong learning (EIS, 2009). Tertiary education has been found to be a decisive link between technological development and economic growth, social progress, and the wellbeing of the environment. Their role is more and more important throughout the transformation to a knowledge-based economy. Estonia's human development levels (see section 4.4) have indicated that the requisite educational levels have been existent since the first independence, which enabled increased technology absorptive capacity and readiness for the e-revolution experienced in Estonia. Education and life-long learning are therefore key inputs in the innovation- and technology-led economic growth model.

6.4.5. Leveraging regional innovation capability

In section 4.7, the spatial analysis indicated that there is unequal growth in the EU region, which is converging and that its effects may be more obvious in the longer term than in the shorter term. What are the implications for Estonia and other countries attempting to escape the middle-income trap?

The EU region is undergoing economic transformation, so how to control and narrow the regional development gap through effective interventions is a key objective for EU regional macroeconomic policy. The same section (4.7) indicated that the spatial interaction has been concentrated in Central Europe for decades. The excessive concentration of innovation resources and serious imbalance in innovation capability needs improvement to avoid a widening regional disparity in innovation levels. Therefore, in formulating innovation policies for the EU region, attention should be paid to the spatial interaction mechanism and how to make full use of the regional innovation resource endowment and differences in innovation capability to reduce the gap identified in EU regional economic development. Estonia's distance from Central Europe yet having attained digital success serves as a country model for the development of regional macroeconomic regulation for other countries to catch up, in terms of economic development levels.

6.5. Chapter summary

In this chapter, an assessment was made to establish whether the evidence provided met both the necessary and sufficient standard for establishing causation in the sense of Beach and Pedersen (2013), using the matrix for assessing the uniqueness and certainty of evidence. The methods of elimination and decision criteria were developed and employed in agreement with Bennett's (2010) suggestions in regard to process tracing. A possible alternative outcome was considered to determine the possibility of serving as a secondary outcome. Although the secondary outcome turned out to be a straw-in-the-wind, it enabled clues to suggest that Estonia's digital transformation was strategy-driven, though it had been suggested that it was ad hoc and informal, based on the evidence gathered in the auxiliary outcome test. Therefore, a Digital Plan explaining Estonia's accelerated economic development was proposed. The development of this plan was preceded by an analysis of the causal sequence framework, the hypothesized mechanism and causal process, resulting in a revised causal sequence framework. The analysis suggested that both endogenous growth theory and socio-technical theory assertions are supported while analysing Estonia's digital success story. Recommendations emanating from the analysis are outlined. It is important to note that while the research findings resulting from the explaining-outcome process-tracing are not generalizable, there is no restriction that the recommendations resulting from the research findings in this work cannot be extrapolated for other countries. It is rather more important to be cautious in generalizing causal inferences reached based on case-specific observed evidence gathered and analysed about causation and how it was understood and implied in this work and the further conclusions made outside of this work.

7. CONCLUSIONS

In this concluding Chapter, the research design (research scope and motivation, research problem and questions, review of literature and research methods and the research process (actions taken to collect data and analyze, process-trace, descriptive and interpretive case study and conclusions) in identifying, assessing, and analyzing data towards seeking answers to the RQs and research outcome (results) are described in section 7.1. A summary of main findings (section 7.2) is presented, followed by a discussion of theoretical and policy implications (section 7.3), in addition to limitations of the study, and possibilities for future research (section 7.4).

7.1. Research design, process and outcomes

The aim of this thesis was to identify the determinants of economic development and explore the implications for Estonia's economic development since 2000. To achieve this research aim, the research problem (RP) was formulated as follows: **What are the determinants of economic growth and economic development in Estonia between 2000 and 2015?** The research problem was decomposed into Four (4) RQs (see section 3.4)

Given the nature of the research problem, the **Interpretivist** research philosophy was applied in the dissertation, in agreement with Klein and Myers (1999) to allow for socially constructed and contextualized meanings and interpretations. In agreement with Grenz (1995), the **postmodernist** paradigmatic perspective was applied, in the sense that truth always possesses a local nature and context which is subject to change. Process tracing, specifically **explaining-outcome process-tracing,** was employed as a methodology and method. Consequently, four (4) tests were conducted to explore six (6) hypotheses based on the matrix for assessing the certainty and uniqueness of evidence as prescribed by Beach and Pedersen (2013), with a seventh Hypothesis (Hn) seeking to analyse the outcome of all tests performed in agreement with Bennett (2010) and Colier (2011). Basic underlying assumptions were considered in relation to the dissertation which laid out the theoretical expectations for this work, including:

1. That there is a causal relationship between the determinants of economic growth and the economic development of a country.
2. That the set of determinants is dependent on the country observed and the period studied.
3. That the impact of the determinants is homogenous across the period studied.
4. That there are two types of economic growth determinants in the innovation- and technology-led economy: direct and indirect determinants.
5. That there is no existing theory defining the determinants of economic growth for a country with an innovation- and technology-led economy.

An iterative research process was used to extract causal interpretations through a robust research design and a novel contextualization and operationalization of the methodology and methods. During the process, a conceptual model was developed establishing the likely relationships among explanatory variables (economic growth factors), the intervening variable (economic innovation) and the dependent variable (economic growth and development) as well as the auxiliary outcome – a digital knowledge-driven economy. Alternative choices were also considered, and counterfactual outcomes also examined closely to ensure that they did not have the capacity to weaken the primary hypotheses. The procedure meant finding evidence for both the primary hypotheses and rival hypotheses in addition to introducing auxiliaries into the causal sequence framework.

7.2. Summary of research findings

The research problem is resolved to an extent that causal links between the selected growth factors and economic growth and development were established through various quantitative and qualitative analyses of data on Estonia, as follows:

For **RQ1**, in reviewing the literature and analysing data, the relationships between direct **economic growth factors** (R&D expenditure, number of patent applications, human capital development, technological innovations and regional innovation capability), **indirect economic growth factors** (ICT infrastructure, innovation policy, and technology governance) and economic growth and economic development were described.

For **RQ2**, the smoking gun test results indicated that R&D expenditure and number of patent applications did not have a significant role in predicting the economic growth of Estonia. Meanwhile, human capital development and technological innovations were identified as determinants of Estonia's economic development, having evidenced a causal impact on economic development. Further, for the EU region, the results of the panel data analyses – spatial data estimations and modelling – suggested that R&D expenditure did but number of patent applications did not present as strong explanatory factors in EU regional economic development, confirming prior studies about unbalanced growth (see section 2.5). The possible reasons were explained.

For **RQ3,** the Hoop test of ICT infrastructure and straw-in-the-wind test of innovation policy and technology governance suggested that the economic growth model of Estonia was undergoing a transformation with more consumption, services and higher value-added manufacturing and innovation, among others. The number of innovation policies, projects and programmes churned out prior to the study period and during the period, the role of the database infrastructure x-road as an integrator of splinter information systems, and the sheer magnanimity of cross-political party support for Estonia's digital transformation were highlighted.

For **RQ4,** recommendations concerning innovation governance and technology management in Estonia resulting from the entire process-tracing exercise were outlined. In response to this question, an analysis of exogenous and endogenous pathways of Estonia's economic development were explored, leading to practical recommendations in section 6.4

A revised causal puzzle was developed in analysing the pathways to Estonia's economic development: **Growth determinants that stimulate economic innovation for innovation- and technology-led growth include platform enabled services and online platforms.**

The insights developed from the analysis suggested that the digital economy was not being adequately captured in economic analyses or not at all in Estonia's development. The steps to take advantage of the digital economy and society were covered in section 6.4.

The **research findings** are summed up as follows:

First, the results obtained in the study support endogenous growth theory that R&D activities affect economic growth positively, promoting technological innovation and increasing the productivity growth of a nation in the sense of Romer (1990). Even though the statistical results were not entirely favourable in the case studied, conclusions can be made in their favour due to stronger and already tested assumptions, for example in Sveikaukas (2007), De loo and Soete (1999), Comin et al. (2004), Westmore (2014), Ulku (2004) and Pessoa (2007).

Second, prior research studies have suggested that an effective patent system enables the spread of innovation across an economy. In the analysis of Estonia's situation, it turned out that the number of patent applications were not significant in Estonia's development and suggesting low technological innovation. However, R&D expenditure was confirmed as being a major predictor of economic growth among the 26 EU countries analysed in agreement with Romer (1990), Jones (1995) and Grossman and Helpman (1994).

Third, human capital development and technological innovation are key drivers of economic growth and national development in agreement with previous studies such as the OECD report (1993, p.29), Solow (1956), Schumpeter (1912, 1934, 1939) and Wong et al. (2005).

Further, in relation to regional capability and economic development, the spatial data analysis revealed the clusters that were driving economic convergence in the EU region. In agreement with prior empirical studies such as Baumol (1986) and Barro and Sala-i-Martin (1992) on the convergence of income level differences in the same region, development levels regionally among advanced economies have converged. Furthermore, it was found that ICT infrastructure is significant as a driver of economic innovation in the innovation- and technology-led economy. While this study could not confirm its place in the economic growth of Estonia over the study period based on the Hoop test, it could be suggested, however, that ICT infrastructure investments positively impacted economic innovation.

Now, technology governance and innovation policy did not turn out to be straws-in-the-wind but possible smoking guns, suggesting that with a different methodology different results could be obtained regarding its role in the innovation- and technology-led economy. Typically, the effects of innovation policy on economic growth and development is often not measured directly yet remains a powerful predictor of economic growth and development. All the same, in the analysis in this work, the assumptions of Hypotheses 1–3 were significantly weakened by the results of the statistical analyses, strengthening the assumptions of technology governance and innovation policy in economic growth analysis, such as in this dissertation.

The matrix used in the elimination of hypotheses is considered significant in the sense that, two tests were passed and one remained unconfirmed, yet the weight of the evidence submitted together for H_1 to H_6 provide ample credence and answer the RP; more specifically, the growth factors established in this work were seen as having evidenced a causal impact on Estonia's economic development.

While analysing the causal mechanisms and the process toward making causal inferences and interpretations, it was found that the two pathways analysed here – the endogenous growth pathway and the socio-technical pathway – have a commonality: technology and innovation. For the endogenous growth pathway, ideas are significant while for the socio-technical pathway, ICT infrastructure investment is considered most crucial. It becomes obvious from all the factors considered in the hypothesized mechanism, that causal processes and inferences are embedded in each of these two theoretical pathways.

In view of the above research findings, some implications, first for theory, then for policymakers and country managers are suggested.

7.3. Implications of the study

7.3.1. Theoretical implications

The contributions of this work to theory are as follows:

In terms of theoretical implications, an interesting way of contextualizing and operationalizing process tracing is provided in the work. This work will serve as a basis for future research designs involving process tracing in business and management studies, as, for a long time since its inception, process tracing has remained the reserve of social and political scientists. Additionally, the Conceptual Model (see section 2.7) developed in this work serves as a useful resource package for future studies to leverage. Furthermore, the revised causal sequence framework (section 6.3) provides an opportunity for subsequent studies of the relationships between the factors identified in this study.

Second, while several factors were considered in this study, the impact of R&D expenditure in predicting economic growth continues to be relevant to innovation- and technology-led economic growth and development.

Although neoclassical economic theory predicts economic convergence, the empirical evidence has been a subject for debate. While some suggest the use of time series analyses, others suggest cross-sectional methods to test the convergence hypothesis. This work has provided support that the results are valid in the neoclassical sense. In using panel data analysis, which combines both cross-sectional and time series qualities, this study provided reinforcement by confirming the superiority of panel data analysis and spatial effects' analysis using spatial estimations and modelling.

Another implication for researchers is in the research methods used in the studies on this quality. Of the 30 reviewed papers (see Appendix 1) seeking to establish a causal link between growth factors and economic growth, all studies employed predominantly quantitative methods in their analysis. The qualitative logic behind the quantitative studies of such studies, may be missing. In this work, both quantitative and qualitative methods were used.

7.3.2. Policy implications

The implications for practice are as follows:

First, the importance of different types and sources of technological change as determinants of economic growth and development has been analysed. The implication for practice is for decision-makers to weigh the different growth factors and identify which ones will lead to increased productivity growth so that resources can be appropriately directed. Wei, Xie and Zhang (2017) established that government misallocation of resources is a common reason for the backward economic growth and lag in development levels, especially in developing economies. Effective management of public resources, development of nongovernment networks of entrepreneurs and innovators means a forward-looking government to lead Estonia's economic transformation process in its more complex next phase.

Second, the literature has suggested that there is an association between R&D investments as a key input for patents (see section 2.5). Even though the economic growth rate of Estonia is one of the fastest in the EU, the intensity of R&D activities, according to EIS, is generally low. Employment in medium-high and high-tech manufacturing and knowledge-intensive services remains modest. The government of Estonia needs to increase subsidies to firms in support of R&D activities to promote technological innovation and stimulate the necessary conducive business climate for growth in the tertiary sector of the economy for increased employment in the sector. The number of patent applications will increase with continued investment in human capital development and increased government subsidies for R&D activities, which will drive technological innovations and entrepreneurial activities greatly.

Third, growth in labour productivity is inextricably linked to overall economic growth. Potential growth comes from the sum of the workforce and growth in its labour productivity. This means keeping an eye on wages and wage levels juxtaposed against shrinkage in the absolute size of the working age cohort (15–60 age bracket), but at the same time, taking steps to avoid stagnation or regression in the labour force. By the way, the level of human capital has been known to affect the rate of regional economic convergence.

Further, governments must pay attention to the spatial interaction mechanism and make full use of regional innovation resource endowment in innovation ability to reduce the gap in regional economic development. In the case of Estonia, this is reflected in the wage gap, which is causing a brain drain as a result, significantly affecting the ICT sector, as specialists continue to leave Estonia in search of incomes commensurate with their skill levels.

Furthermore, even with the shortage of patents, doctoral graduates, and participants in lifelong learning per inhabitant, the high share of tertiary-educated persons and high levels of innovativeness of enterprises present clear advantages for Estonia to leverage. These advantages include a high share of innovative enterprises in respect to technological innovations as well as non-technological innovations, innovation expenditure compared with turnover, and a large number of enterprises engaged in innovation cooperation.

Finally, the Estonian government and parliament each have roles to perform to ensure sustained economic growth. For the government, increasing ICT infrastructure investments will go a long way to encourage long-term economic growth. The government must also ensure proper use of these investments, so they are not wasted by unscrupulous individuals with parochial interests. For policymakers, an understanding of the technological progress in the EU region and other successful countries, such as Malaysia and Singapore and neighbouring Finland, may be of great use when developing better policies to govern technological innovation and driving economic innovation. Oftentimes, there has been a lag between the transformations in a country and the legislative changes made, most of which are late and not useful. That means, increased capacity building for legislators and relevant government officials.

7.4. Limitations and future research

While process-tracing has emerged as one of the most valuable methodological tools for the main causal inferences in the social sciences, it is fraught with several challenges. Some are considered below.

Process tracing is relatively new, and therefore ontological questions suffice – how should we understand a causal relationship in terms of regular association (regularity) or as deterministic or probabilistic; whether causality refers to a deeper connection between cause and effect (mechanism); whether mechanisms should be understood as operating solely at micro/actor level or macro/structural level. In addition, epistemological debates about how to observe causal mechanisms – directly or through the implications of their existence – have been lingering for some time without clear answers in the process-tracing methodological literature. Further, there are no clear-cut approaches defined for contextualization and operationalization. This has the propensity to introduce researcher bias and subjectivity into a thesis of this nature in the interpretation of causal mechanisms, processes, inferences and causal interpretations. While this could open avenues to challenge the validity and reliability of the research, explaining-outcome process tracing studies focused on single or within case results cannot be generalized for other contexts. In this work, explaining-outcome process tracing is employed more as a research design strategy, combining multiple methods to study the research phenomenon.

What constitutes a minimally sufficient explanation, still stands to be discovered in relation to extracting conclusions from cases. Further work needs to be done in this regard. According to Gerring (2006) and Mackie (1965), cited in Beach et al. (2013), 'sufficiency' is defined as an explanation that accounts for all the important aspects of an outcome with no redundant parts being present.

Proponents and researchers (also known as process-tracers) have warned about the iterative process involved in process tracing, and when to consider a minimally sufficient conclusion. They have suggested having prior knowledge before proceeding with process tracing, in that, to investigate causal relationship, and establish a cause, just like a detective, a researcher must understand the case fully. This could be challenging. There remains much work to be done in defining, delineating and developing process-tracing methods. This work has provided such an example.

Another hurdle that future researchers stand to face is that there are many different concepts of growth and ways of measuring it, both narrower and broader growth concepts. This makes it difficult to provide a scope for growth studies due to the barrage and multiplicity of angles the subject has been considered from.

R&D data are collected through national surveys according to the guidelines laid down in the Frascati Manual (OECD, 2002). These data have proved valuable in many studies; for example, the effects of R&D expenditure on productivity have been estimated using econometric techniques at the country, sector, and firm levels. These data have two main limitations. First, R&D is an input. Although it is obviously related to technological change, it does not measure it. Second, R&D activities do not encompass all the efforts of firms and governments in this area, as there are other sources of technological change, such as learning by doing, which are not covered by this narrow definition.

A patent is a legal property right to an invention, which is granted by national patent offices. A patent gives its owner sole rights (for a certain duration) to exploit the patented invention; at the same time, it discloses the details of the patent to allow broader social use of the discovery. Patent statistics are increasingly used in various ways as indicators of the output of research activities. The number of patents granted to a given firm or country may reflect its technological dynamism, and an examination of the growth of patent classes can give some indication of the direction of technological change. The drawbacks of patents as innovation indicators are well-known. Many innovations are not patented, and some are covered by multiple patents; many patents have no technological or economic value, and others have very high value (see the Patent Manual, OECD, 1994).

Because of the need to place technological innovation in a wider context, both conceptually and in terms of databases, United Nations guidelines and classifications are used as far as possible, notably the System of National Accounts – SNA (CEC et al., 1994) and the International Standard Industrial Classification – ISIC Rev. 3.1 (UN, 2002) and, as this is a joint OECD/Eurostat Manual, the corresponding European standards, notably the Statistical Classification of Economic Activities in the European Community – NACE Rev. 1.1 – series 2E. This requires further exploration.

Now, a critical aspect of this study was investment-specific technological change, embodied in capital assets, and improvements in the quality of labour services generated by human capital development accumulations. The case of Estonia serves as an example to study further the implications of human capital development in the innovation- and technology-led economy.

The pathway to an innovation- and technology-led economic growth model is also amplified in this work, in that further studies are required to concretize the sources of new growth in the innovation age and especially case studies that highlight how countries dealt with the transition from traditional economic growth models, reliant on agriculture and manufacturing to pursue these new growth strategies, reliant on value added services and manufacturing, technological innovation and their possible outcomes. The transition towards new, advanced economy growth drivers offers a route to continued economic development.

REFERENCES

Acemoglu D., Johnson S., & Robinson J. (2002). Reversal of Fortune: Geography and Institutions in the making of the modern world income distribution. Quarterly Journal of Economics 2(2): 70-84

Acemoglu, D. (2012). Introduction to Economic Growth. Journal of Economic Theory, 147(2), 545-550. https://www.doi.org/10.1016/j.jet.2012.01.023

Acemoglu, D., Johnson, S., & Robinson, J. (2004). Institutions as the Fundamental Cause of Long-Run Growth. Retrieved from http://www.nber.org/papers/w10481

Adcock, R. & Collier, D. (2001), 'Measurement Validity: A Shared Standard for Qualitative and Quantitative Research', American Political Science Review, 95 (3), pp. 529–54.

Aghion, P., & Howitt, P. (2015). The Schumpeterian Growth Paradigm. Annual Review of Economics, 7(1), 557–575. https://doi.org/10.1146/annurev-economics-080614-115412

Aigner D.J., Hsiao C, Kapteyn A, & Wansbeek T.J. (1984) Latent variables in econometrics. Handbook of econometrics, vol II. North-Holland, Amsterdam, pp 1321–1393

Alvarez-Pelaez, Maria J. & Groth, Christian, (2005). Too little or too much R&D? European Economic Review, Elsevier, vol. 49(2), pages 437-456, February.

Angen, M.J. (2000). Evaluating Interpretive Inquiry: Reviewing the Validity Debate and Opening the Dialogue. Qualitative Health Research, 10, 378-395. http://dx.doi.org/10.1177/104973230001000308

Anselin, L., (1988). Spatial Econometrics: Methods and Models, Kluwer Academic Publishers, Dordrecht.

Anselin, L., & Rey, S. J. (1997). Introduction to the Special Issue on Spatial Econometrics. International Regional Science Review, 20(1–2), 1–7. https://doi.org/10.1177/016001769702000101

Arbia, G., & Piras, G. (2011). Convergence in Per-capita GDP across European Regions using Panel Data Models Extended to Spatial Autocorrelation Effects. SSRN Electronic Journal, (August), 25–29. https://doi.org/10.2139/ssrn.936327

Arbia, G., Basile, R. & Salvatore, M (2002). Regional convergence in Italy 1951-1999: a spatial econometric perspective, Paper presented at the 17th annual congress of the European Economic Association, Venice, August 2002.

Arbia, G., Basile, R. & Salvatore, M. (2003). Spatial Effects on Regional Growth. A Parametric and a Nonparametric Approach, paper presented at the congress Analytical Frontiers in Spatial Aspects of Economic Development May 29, 2003, WIDER, Helsinki

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and An Application to Employment Equations. The Review of Economic Studies, 58 (2), 277-297.

Arrow K. (1962). Economic Welfare and the Allocation of Resources for Invention. In R. Nelson (ed.), The Rate and Direction of Inventive Activity, pp. 609-26, Princeton, NJ: Princeton University Press. https://www.doi.org/10.1515/9781400879762-024

Arundel, A., & Kabla, I. (1998). What percentage of innovations are patented? Empirical estimates for European firms. Research Policy, 27(2), 127–141. https://doi.org/10.1016/S0048-7333(98)00033-X

Arusha, V. C. (2009). Government expenditure, governance and economic growth. Comparative Economic Studies, 51(3), 401–418.

Asteriou, D., Karagianni, S., & Siriopoulos, C. (2011). Testing the Convergence Hypothesis Using Time Series Techniques: The Case of Greece 1971-1996. Journal of Applied Business Research (JABR), 18(2). https://doi.org/10.19030/jabr.v18i2.2123

Aubert, J.-E., Chen, D., Kim, R., Kuznetzov, Y., Larsen, K., Theus, F., & Welsum, D. V. (2010). Innovation policy: A Guide For Developing Countries: Main report (English). In World bank. Retrieved from http://documents.worldbank.org/curated/en/251181468340760891/Main-reportcited

Ayres, C., E. (1962). The theory of economic progress. A Study of the Fundamental Economic Development and Cultural Change. New York: Schocken

Baltagi, B., (2001). Econometric Analysis of Panel Data, 2nd ed., John Wiley and Sons, Chichester.

Baltagi, B., & Li, D., (2006). Prediction in the panel data model with spatial correlation: the case of liquor. Spatial Economic Analysis 1, 175–185

Baltagi, Badi H., & Levin, Dan, (1986). Estimating Dynamic Demand for Cigarettes Using Panel Data: The Effects of Bootlegging, Taxation and Advertising Reconsidered, The Review of Economics and Statistics, MIT Press, vol. 68(1), pages 148-155, February.

Baltagi, Badi H. (2005). Econometric Analysis of Panel Data, 3rd edition. Chichester: Wiley

Baltagi, H. B. (2007). Comments on Panel Data Analysis-Advantage and Challenges. Test 16 (1), 28-30.

Barro, R. & Sala-i-Martin, X., (1992). Convergence. Journal Of political Economy 100, 223–251.

Basu, S., Fernald, John G. & Shapiro, M. D., (2001). Productivity growth in the 1990s: technology, utilization, or adjustment? Carnegie-Rochester

Conference Series on Public Policy, Elsevier, vol. 55(1), pages 117-165, December.

Baumol, W. J. (1986). Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show. The American Economic Review, Vol. 76(No. 5), pp. 1072{1085.

Baumont, E., LeGallo, (2002), The European Regional Convergence Process, 1980-1995: do Spatial Regimes and Spatial Dependence matter? Economics Working Paper Archive at WUSTL

Baumont C., Ertur C. & Le Gallo, J. (2002). Estimation Des Effets De Proximité Dans Le Processus De Convergence Régionale : Une Approche Par L'économétrie Spatiale Sur 92 Régions Européennes (1980-1995). Revue D'économie Régionale Et Urbaine, Armand Colin, vol. 0(2), pages 203-216.

Beach, D., & Pedersen R. (2013) Process Tracing Methods, Process and Guidelines, University of Chicago Press

Bell, M., and K. Pavitt. (1993). Technological Accumulation and Industrial Growth: Contrasts Between Developed and Developing Countries. Industrial and Corporate Change 2 (2): 157–210. doi: 10.1093/icc/2.1.157

Bennett, A. (1992) The Operation of the Estonian Currency Board. IMF WP/92/03.

Bennett, A. (1993) The Operation of the Estonian Currency Board. IMF Staff papers. Vo1.40, No.2, June 1993.

Bennett, A. (2010). Process tracing and causal inference. In rethinking social inquiry: diverse tools, shared standards, 2nd ed., ed. Henry E. Brady and David Colier, 207-19. Lanham, MD. Rowman and Littlefield.

Bennett, A. (2014). Process Tracing with Bayes: Moving Beyond the Criteria of Necessity and Sufficiency. Qualitative & Multi-Method Research, 46–51.

Bennett, A. and Checkel, J.T. (2015), Process Tracing: From Philosophical Roots to Best Practices, in A. Bennett and J.T. Checkel (eds.), Process Tracing in the Social Sciences: From Metaphor to Analytic Tool (Cambridge: Cambridge University Press), pp. 3–37.

Bennett, Andrew. (2008a). Process-Tracing: A Bayesian Perspective. In Oxford Handbook of Political Methodology, 702–21. Oxford: Oxford University Press.

Bennett, Andrew. (2008b). The Mother of All "Isms": Organizing Political Science around Causal Mechanisms. In Revitalizing Causality: Realism about Causality in Philosophy and Social Science, 205–19. London: Routledge

Bergh, J.C.J.M. van den (2001). Ecological economics: themes, approaches, and differences with Environmental Economics. Regional Environmental Change 3(1): 13-23.

Bergh, J.C.J.M. van den, A. Ferrer-i-Carbonell en G. Munda, (2000). Alternative models of individual behaviour and implications for environmental policy. Ecological Economics 32(1): 43-61.

Bergh, J.C.J.M. van den, & J.M. Gowdy (2003). The micro foundations of macroeconomics: an evolutionary perspective. Cambridge Journal of Economics 27(1): 65-84.

Birchall, D., Chanaron, J.-J., & Tovstiga, G., (2011). Innovation performance measurement: current practices, issues and management challenges. International Journal of Technology Management, 56(1): 1–20.

BOFIT Discussion papers, Bank of Finland, Institute of Economies in transition. [Available] http://www.bofit.fi/en/

Boldeanu, F., & Constantinescu, L. (2015). The main determinants affecting economic growth. Bulletin of the Transilvania University of Brasov. Economic Sciences. Series V, 8(2), 329.

Boldrin, M., & Levine, D. K. (2012). The Case against Patents FRB of St. Louis Working Paper No. 2012-035A, Available at SSRN: https://ssrn.com/abstract=2148738 or http://dx.doi.org/10.2139/ssrn.2148738

Bostrom, R. P. &Heinen, J.S. (1977) MIS Problems and Failures: A Socio-Technical Perspective, Part II: The Application of Socio-Technical Theory¨, MIS Quarterly, Vol. 1, No. 3, http://www.iei.liu.se/is/edu/courses/725a04/kurslitteratur/1.107778/MISproblemsII.pdf.

Braconier, H. (2000). Do Higher Per Capita Incomes Lead to More R&D Expenditure? Review of Development Economics, 4 (3), 244–257.

Branscomb L. M. (2001). Technological Innovation. In Neil J. and Paul B. Baltes, editors, International Encyclopedia of Social and Behavioral Sciences. Oxford: Elsevier Science Ltd., 2001.

Breusch, T. S., and A. R. Pagan. (1980). The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. Review of Economic Studies, 47(1): 239-253

Bresnahan T. & Brynjolfsson E. & Hitt, L.M. (2002). Information Technology, Workplace Organization, And the Demand for Skilled Labor: Firm-Level Evidence, The Quarterly Journal of Economics, MIT Press, vol. 117(1), pages 339-376, February.

Brinkman, R. (1995). Economic Growth versus Economic Development: Toward a Conceptual Clarification. Journal of Economic Issues, 1995, vol. 29.

Brynjolfsson, E. and Hitt, L. (1993). Is Information Systems Spending Productive. In New Evidence and Results, Mimeograph.

Brynjolfsson, E. (1993). The Productivity Paradox of Information Technology. Communications of the ACM, 36(12): 67–77.

Brynjolfsson E. & Kahin B. (2000). Understanding the Digital Economy: Data, Tools, and Research, The MIT Press

Burlamaqui L., & Kattel, R. (2016). Development as leapfrogging, not convergence, not catch-up: towards schumpeterian theories of finance and development. Review of Political Economy, Taylor & Francis Journals, vol. 28(2), pages 270-288, April.

Bwanakare, S. (2019). The System of National Accounts. In Non-Extensive Entropy Econometrics for Low Frequency Series. https://doi.org/10.1515/9783110605914-007

Callon, M. (1986). Some Elements of the Sociology of Translation: Domestication of Scallops and the Fishermen of St Brieuc Bay. In Power, Action and Belief, edited by J. Law, 196–233. London: Routledge & Kegan Paul.

Carroll, C. D. (2019). The Romer (1986) Model of Growth. 1(1986), 8–9.

Cantwell, J. A. (1999). Innovation as the Principal Source of Growth in the Global Economy. In D. Archibugi, J. Howells and J. Michie (eds.), "Innovation Policy in a Global Economy", Cambridge: Cambridge University Press.

Cantwell, R. (1999) Putting Data to Work—GIS and Site Selection Studies for Waste Management Facilities. Conference Proceedings, Eurogise 1999, Galway, 26 March 1999, 152-163.

Carlson, L., & Sullivan, J. F. (2002). Between Invention and Innovation. Director, 21-2.

Carrington, A. (2003): A Divided Europe? Regional Convergence and Neighborhood Spillover Effects. Kyklos, 56, 381-394.

Carroll, G. R. (1997). Long Term Evolutionary Change in Organizational Population: Theory, Models and Empirical Findings from Industrial Demography. Industrial and Corporate Change, Vol. 6, pp. 119-145

Carter, S. M., & Little, M. (2007). Justifying Knowledge, Justifying Method, Taking Action: Epistemologies, Methodologies, and Methods in Qualitative Research. Qualitative Health Research, 17(10), 1316–1328. https://doi.org/10.1177/1049732307306927

Case, A., (1991). Spatial patterns in household demand. Econometrica 59, 953–965

Caselli F., Coleman W. J. (2001): The US Structural Transformation and Regional Convergence: A Reinterpretation. Journal of Political Economy 109:584e616, 2001.

Cass, D. (1965). Optimum Growth in an Aggregative Model of Capital Accumulation. The Review of Economic Studies, Vol. 32(No. 3), pp. 233-240.

Checkel, J. T. (2008). Tracing Causal Mechanisms. International Studies Review 8 (2): 362–70

Chirwa, T. G., & Odhiambo, N. M. (2016). Macroeconomic determinants of economic growth: A review of international literature. South East European Journal of Economics and Business, 11(2), 33–47. https://doi.org/10.1515/jeb-2016-0009

Choi, I. (2001). Unit Root Tests for Panel Data. Journal of International Money and Finance, 20, 249-272.

Colecchia, A. & Schreyer, P. (2002). ICT Investment and Economic Growth in the 1990's: Is the United States A Unique Case? A Comparative Study of Nine OECD Countries, Review of Economic Dynamics 5(2): 408–442. https://doi.org/10.1006/redy.2002.0170

Collier, D. (2011) Understanding Process Tracing (2011). PS: Political Science and Politics, Vol. 44, No. 4, pp. 823-830, October 2011. Available at SSRN: https://ssrn.com/abstract=1856702

Comin D. & Hobijn, B. (2004). Neoclassical Growth and the Adoption of Technologies. NBER Working Papers 10733, National Bureau of Economic Research, Inc.

Conte, A. (2006). The Evolution of the Literature on Technological Change over time: A Survey. Papers on Entrepreneurship, Growth and Public Policy.

Cornell (2016). About the GII. Global Innovation Index [Online]. Available at: https://www.globalinnovationindex.org/about-gii

Cummins, J. G. & Violante, G. L. (2002). Investment-specific technical change in the U.S. (1947–2000): measurement and macroeconomic consequences, Review of Economic Dynamics 5(2): 243–284. https://doi.org/10.1006/redy.2002.0168

Czernich, N., Falck, O., Kretschmer, T., & Woessmann, L. (2009). Broadband Infrastructure and Economic Growth. CESifo Working Paper Series No. 2861, Available at SSRN: https://ssrn.com/abstract=1516232

Data Exchange Layer of Information Systems (2008), 'Infosüsteemide andmevahetuskiht,' Riigi Teataja, RT I 2008, 18, 129. Vabariigi Valitsuse määrus. [online] https://www.riigiteataja.ee/akt/12956835

Davidson, R., and MacKinnon J. G. (1993), Estimation and Inference in Econometrics. New York: Oxford University Press

De Long, J. (1988). Productivity Growth, Convergence, and Welfare: American Economic Review, 78(5), 1138–1154.

De Loo, I. & Soete, L., (1999). The Impact of Technology on Economic Growth: Some New Ideas and Empirical Considerations. Research Memorandum 017. Maastricht University, Maastricht Economic Research Institute on Innovation and Technology (MERIT).

DeLong, J. B., Claudia G., and Katz L. (2003). Sustaining U.S. Economic Growth. In H. Aaron, J. Lindsay, and P. Nivola, eds., Agenda for the Nation. Washington, D.C.: Brookings Institution Press, pp.17–60.

Denison, E. F. (1964). The Unimportance of the Embodied Question. The American Economic Review, Vol. 54(No. 2, Part 1), pp. 90-93.

Department for Business-Innovation and Skills. (2011). Sources of economic growth: Trade and Investment Analytical Papers Topic 6 of 18. BIS Research Paper, 15. Retrieved from https://www.gov.uk/government/publications/sources-of-economic-growth

Diamond, P. A. (1965). Disembodied Technical Change in a Two-Sector Model. The Review of Economic Studies, Vol. 32(No. 2), pp. 161-168.

Digital Economy Report (2019). Overview. The Financial Crisis and the Global South, 4(June), 64. https://doi.org/10.1111/j.1755-6988.1986.tb00583.x

Domar, E. D. (1946). Capital Expansion, Rate of Growth, and Employment. Econometrica, Vol. 14(No. 2), pp. 137-147.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G., & Soete, L. (1988). Technical Change and Economic Theory. LEM Book Series. https://doi.org/10.2307/2234048 Edari R (1976). Social Change. Dubuque: Lowe.

Dosi, G. (1997). Opportunities, Incentives and the Collective Patterns of Technological Change. The Economic Journal, Vol. 107(No. 444), pp. 1530-1547

Dowrick, S., & Nguyen, D. (1989). OECD Comparative Economic Growth 1950-85: Catch-Up and Convergence. The American Economic Review, 79(5), 1010-1030. Retrieved August 18, 2020, from www.jstor.org/stable/1831434

Ducharme, L. M., Arslanalp, S., Goksu, B., Kostroch, D., Carlos Moreno-Ramirez, J., Martins, M., Jamasali, J. K. (2018). Measuring the Digital Economy. International Monetary Fund, 3(February).

Dudovskiy, J. (2018). The Ultimate Guide to Writing a Dissertation in Business Studies: A step-by-step Assistance.

Durlauf., B. (1996). Interpreting Tests of The Convergence Hypothesis. Journal of Econometrics, Vol. 71, pp. 161–173.

Durlauf, S.N., Johnson, P.A. and Temple, J.R.W. (2005). Chapter 8. Growth Econometrics, Handbook of Economic Growth. Amsterdam, North-Holland, pp. 555–677.

Dusollier, S. (2007). Sharing Access to Intellectual Property Through Private Ordering. Chicago Kent Law Review, 2007, 82 (3), pp. 1391–1435.

Dutta, S., & Mia, I. (2010). Global Information Technology Report 2009–2010. In World Economic Forum Yearly. Retrieved from https://www.itu.int/wsis/implementation/2010/forum/geneva/docs/publications/GITR 2009-2010_Full_Report_final.pdf

Dutta, S., & Mia, I. (2011). The Global Information Technology Report 2010–2011: Transformations 2.0. In Technology. https://doi.org/10.3359/oz0304203

Eesti Koostöökogu. (2013). Estonian Human Development Report 2012/2013: Estonia in the World.

Eesti Pank Press Release (2016) Eesti Pank, https://www.eestipank.ee/en/press/2016

Eichengreen, B., Park, D., & Shin, K. (2011). When Fast Growing Economies Slow Down: International Evidence and Implications for China. NBER Working Paper Series, Retrieved from http://www.nber.org/papers/w16919

Elhorst, J.P. (2003). Specification and Estimation of Spatial Panel Data Models. International Regional Science Review 26, 244–268.

Elhorst, J. P. (2001), Panel Data Models Extended to Spatial Error Autocorrelation or a Spatially Lagged Dependent Variable, University of Groniger Research Report 01c05

Emery, F. E., & Trist, E. L. (1965). The Causal Texture of Organizational Environments. Human Relations, 18(1), 21–32. https://doi.org/10.1177/001872676501800103

Eriksson, P., and Kovalainen, A. (2011). Qualitative Methods in Business Research. Sage Publications. https://dx.doi.org/10.4135/9780857028044

Esfahani, H.S. and Ramírez, M.T. (2003) Institutions, Infrastructure, and Economic Growth. Journal of Development Economics, 70, 443-477

Estonia (1992). Economic Review. Washington: IMF

Estonia (2020). Digital Agenda 2020 for Estonia (Updated 2018, Summary). 2018.

Estonia 2020 reform programme. (2015). [Online] Available: https://riigikantselei.ee/en/supporting-government/national-reform-programme-estonia-2020

Estonia World Ranking (2015). [Online] Available: http://www.vm.ee/en/estonias-position-international-rankings-2014-2015

Estonia. (1992). Economic Review. Washington: IMF.

Estonia. (1993a). The Transition to a Market Economy. Washington. World Bank

Estonia's broadband strategy. (2009). [Online] Available: http://elasa.ee/public/files/ESTWIN_network%20track_20090420.pdf

Estonian Parliament (1998). Principle of Estonian information policy. Available at https://www.riigiteataja.ee/akt/75308 (in Estonian).

European Innovation Scoreboard, EIS. (2009). [Available] https://ec.europa.eu/growth/content/european-innovation-scoreboard-2009-0_en

Eurostat, (2017a). European Innovation Scoreboard. European Commission. [Online]. Available at: http:// ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_cs

Evenson, R. E., and L. E. Westphal. (1995). Technological Change and Technology Strategy. In Vol. 3A of Handbook of Development Economics, edited by J. Behrman and T. N. Srinivasan, 2209–2299. Amsterdam: North-Holland.

Falleti, T.G. and Lynch, J. (2009), 'Context and Causal Mechanism in Political Analysis', Comparative Political Studies, 42 (9), pp. 1143–66.

Fearon, J. (1991). Counterfactuals and Hypothesis Testing in Political Science. World Politics, 43(2), 169-195. doi:10.2307/2010470

Feldman M.P. et Florida R. (1994). The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States. Annals of the Association of American Geographers, Vol. 84, n°2, p.210-229.

Ferdows, K., & Rosenbloom, R. S. (1981). Technology Policy and Economic Development: Perspectives for Asia in the 1980's. Columbia Journal of World Business, pp. 36–46.

Frascati manual (2002). OECD. [online] https://www.oecd-ilibrary.org/science-and-technology/frascati-manual-2002_9789264199040-en

Furman, J. L., Porter, M. E., & Stern, S. (2002). The determinants of national innovative capacity. Research Policy, 31(6), 899–933. https://doi.org/10.1016/S0048-7333(01)00152-4

Gackstatter, S., Kotzemir, M., & Meissner, D. (2014). Building an Innovation-Driven Economy - the Case of BRIC and GCC Countries. Foresight, 16(4), 293–308. https://doi.org/10.1108/FS-09-2012-0063

Geels, F.W. (2002). Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and A Case-Study. Research Policy 31, 1257–1274.

Geels, F.W. (2004). From Sectoral Systems of Innovation to Socio-Technical Systems: Insights About Dynamics and Change from Sociology and Institutional Theory. Research Policy 33, 897–920.

George A. L., and Bennett A. (2005). Case Studies and Theory Development in the Special Sciences, The MIT Press

George, A.L. (1997). The Role of the Congruence Method for Case Study Research. Available from: http://www.ciaonet.org/wps/gea01/index.html.

Gerring, J. (2006). Case Study Research: Principles and Practices (pp. 172-186). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511803123.010

Gittleman, M., Wolff, E. N. (1995). R&D Activity and Cross-Country Growth Comparisons. Cambridge Journal of Economics, 19, 189-207

Glennan, S. S. (1996). Mechanisms and the Nature of Causation. Erkenntnis 44 (1): 49–71.

Godin, B. (2003). The Emergence Of S&T Indicators: Why Did Governments Supplement Statistics with Indicators? Research Policy, 32(4): 679–691.

Goedhuys, M. (2007). Learning, Product Innovation and Firm Heterogeneity in Developing Countries: Evidence from Tanzania. Industrial and Corporate Change, Oxford University Press, vol. 16(2), pages 269-292

Graham, Gerald S. (1956). The Ascendancy of the Sailing Ship 1850-85. The Economic History Review, New Series, Vol. 9(No. 1), pp. 74{88.

Greene, W. H. (2000). Econometric Analysis 4th Ed.

Greene, W. H. (2008). Econometric Analysis, 6th ed. Upper Saddle River, NJ: Prentice Hall.

Greiner, W., Semmler, W. and Gong G. (2005). The Forces of Economic Growth - A Time Series Perspective. Structural Change and Economic Dynamics, vol 17, issue 1, 116-120. Princeton University Press, Princeton and Oxford.

Grenz, S., J. (1996). A Primer on Postmodernism. Grand Rapids: Eerdmans, 1996.

Griliches, Z. (1998). R & D and productivity: The Econometric Evidence. University of Chicago Press.

Griliches, Z., & Lichtenberg, F. (1984). R&D and Productivity Growth at the Industry Level: Is There Still a Relationship? NBER. University of Chicago Press.

Griliches, Z., & National Bureau of Economic Research. (1984). R&D, Patents, And Productivity. University of Chicago Press.

Grossman, G. M., Helpman, E., Bernanke, B., Black, F., Campbell, J., Dixit, A., Trajtenberg, M. (1993). Endogenous Innovation in The Theory of Growth. NBER Working Paper Series

Groth, C. (1988). Discussion Papers. Economic Outlook, 12(9), 62–63. https://doi.org/10.1111/j.1468-0319.1988.tb00411.x

Grupp, H. And Mogee, M. E. (2004). Indicators for National Science and Technology Policy: How Robust Are Composite Indicators? Research Policy, 33(9): 1373–1384.

Grupp, H. & Schubert, T. (2010). Review and New Evidence on Composite Innovation Indicators for Evaluating National Performance. Research Policy, 39(1): 67–78

Guellec, D., van Pottelsberghe de la Potterie, B. (2004). From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter? Available at SSRN: https://ssrn.com/abstract=565065

Guo, Y., Wang, B. (2013). Study on the Economic Growth of Patent Output in the High-tech Industry. Journal of Management and Sustainability, 3 (1), 103-107

Hahn, F., & Matthews, R. (1994). Nicholas Kaldor (Lord Kaldor), 1908-1986. The Economic Journal, 104(425), 901-902. doi:10.2307/2234984

Ha J., & Howitt P. (2007). Journal of Money, Credit and Banking, 2007, vol. 39, issue 4, 733-774.

Hall B. H., Rosenberg N. (2010.) Financing R&D and innovation, in Elsevier Handbook of the Economics of Innovation, April 2010, pp. 609-639.

Hall, B. (2004). Innovation and diffusion. Available at https://doi.org/doi=10.1.1.70.9798

Hall, B. H. (2011). NBER Working Paper Series Innovation and Productivity. Retrieved from http://www.nber.org/papers/w17178

Hall, B. H., & Mairesse, J. (2006). NBER Working Paper Series Empirical Studies of Innovation in The Knowledge Driven Economy Empirical Studies of Innovation in the Knowledge Driven Economy. Retrieved from http://www.nber.org/papers/w12320

Hall, B. H., Griliches, Z., & Hausman, J. A. (1981). Is There A Lag?

Hall, B. H., Lerner, J., Hall, B. H., & Lerner, J. (2009). The Financing of R&D and Innovation Financing R&D and Innovation. Retrieved from http://www.nber.org/papers/w15325

Hall, Bronwyn H., Adam Jaffe and Manuel Trajtenberg (2005). Market Value and Patent Citations, Rand Journal of Economics, 2005, v36(1, Spring), 16-38.

Hall, P.A. (2003). Aligning Ontology and Methodology in Comparative Research. In J. Mahoney and D. Rueschemeyer (eds.), Comparative Historical Analysis in the Social Sciences (Cambridge: Cambridge University Press), pp. 373–404

Hanke, S. - lonung, L. - Schuler, K. (1992). Monetary reform for a Free Estonia. A Currency Board Solution. Stockholm, SNS Forlag.

Hansen, L. (1982). Large Sample Properties of Generalized Method of Moments Estimators. Econometrica, 50(4), 1029-1054. doi:10.2307/1912775

Hansson, A. - Sachs, l. (1994). Monetary Institutions and Credible Stabilization: A Comparison of Experience in the Baltics. A paper for the conference on "Central Banks in Eastern Europe and in the Newly Independent States."

Hanushek, E. A., and Zhang L. (2009). Quality-consistent Estimates of International Schooling and Skill Gradients. Journal of Human Capital 3, no. 2: 107-143.

Harrod, R. F. (1939). An Essay in Dynamic Theory. The Economic Journal, Vol. 49(No. 193), pp. 14-33.

Hausman, J. A. (1978). Specification Tests in Econometrics. Econometrica, 46(6): 1251-1271

Hayasyi, F. (2000). Econometrics. Princeton, NJ: Princeton University Press

Helpman, E. (1992). Endogenous Theory Macroeconomic Growth. 36, 237–267.

Hirschman, A. O. (1958). The Strategy of Economic Development. New Haven, Conn.: Yale University Press.

Holtz-Eakin, D., Newey W., Rosen, S. H. (1988). Estimating Vector Autoregressions with Panel Data. Econometrica, 56 (6), 1371–1395.

Honohan, P. (1994). Currency Board or Central Bank? Lessons from the Irish pund's Link with Sterling, 1928-79. CEPR Discussion Paper # 1 040.

Hsiao, C. (2003). Analysis of Panel Data (Second Edition). Cambridge: Cambridge University Press.

Hsiao, C. (2006). Panel Data Analysis Advantage and Challenges. WISE Working Paper Series No: 0602.

Hsiao, C. (2016). Dynamic Panel Data Models. Handbook of Empirical Economics and Finance, 373–396. https://doi.org/10.4337/9780857931023.00016

Hsiao, C. (2005). Why Panel Data? IEPR Working Paper No. 05.33, Available at SSRN: https://ssrn.com/abstract=820204 or http://dx.doi.org/10.2139/ssrn.820204

Hughes, T. P. (1983). Networks of Power. Electrification in Western society, 1880–1930. Baltimore: Johns Hopkins University Press.

Hulten, C. R., Dean, E., Harper, M. J., & Conference on Research in Income and Wealth. (2001). New developments in productivity analysis. University of Chicago Press.

Im, K. S., Pesaran, M. H., Shin, Y. (2003). Testing for Unit Roots in Heterogeneous Panels. Journal of Econometrics, 115, 53-74.

Innovate UK. (2015). Digital Economy Strategy 2015-2018. Innovate UK Technology Strategy Board. Retrieved from https://www.gov.uk/government/publications/digital-economy-strategy-2015-2018

ITU (International Telecommunications Union). (2015). Measuring the Information Society Report 2015. International Telecommunication Union. Retrieved from http://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2015/MISR2015-w5.pdf

ITU. (2007). World Information Society Report. 175. Retrieved from http://www.itu.int/osg/spu/publications/worldinformationsociety/2007/WISR07_full-free.pdf

ITU. (2009). Framework for e-Gov toolkit. 1–35.

ITU. (2011). Measuring the Information Society. 174.

Jaffe, A. B., Lerner, J., & Stern, S. (2006). Innovation policy and the economy. 6. National Bureau of Economic Research.

Jalava, J., & Pohjola, M. (2002). Economic Growth in The New Economy: Evidence from Advanced Economies. Information Economics and Policy 14(2): 189–210. https://doi.org/10.1016/s0167-6245(01)00066-x

Jary, D., & Jary, J. (1991) Collins Dictionary pf Sociology. London, HarperCollins.

Jia, X. F., & Ye, H. W. (2015). An Empirical Analysis of The Relationship Between Economic Growth and Environmental Pollution in Hebei Province. Advances in Energy Science and Equipment Engineering - Proceedings of International Conference on Energy Equipment Science and Engineering, ICEESE 2015, 1, 655–660. https://doi.org/10.1201/b19126-135

Jones, C. I., & Paul M. R. (2010). The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital. American Economic Journal: Macroeconomics, 2 (1): 224-45.

Jorgenson, D. & M. Ho (1999). The Quality of the U.S. Work Force, 1948-95, Working Paper, Harvard University

Jorgenson, D. W., Ho, M. S., & Samuels, J. D. (2011). Information Technology and U.S. Productivity Growth: Evidence from A Prototype Industry Production Account. Journal of Productivity Analysis, 36(2), 159–175. https://doi.org/10.1007/s11123-011-0229-z

Jorgenson, Dale, W., & Kevin J. Stiroh. (2000). U.S. Economic Growth at the Industry Level. American Economic Review, 90 (2): 161-167.

Josheski, D., Koteski, C. (2011). The Causal Relationship Between Patent Growth and Growth of GDP with Quarterly Data in the G7 Countries: Cointegration, ARDL and Error Correction Models. MPRA Paper No: 33153.

Kacprzyk, A., & Doryń, W. (2017). Innovation and Economic Growth in Old and New Member States of The European Union. Economic Research-Ekonomska Istrazivanja, 30(1), 1724–1742. https://doi.org/10.1080/1331677X.2017.1383176

Kattel R., and Mergel I. (2018). Estonia's Digital Transformation: Mission Mystique and The Hiding Hand. UCL Institute for Innovation and Public Purpose Working Paper Series, IIPP WP 20(September). Retrieved from https://www.ucl.ac.uk/bartlett/public-purpose/publications/2018/sep/estonias-digital-transformation-mission-mystique-and-hiding-hand

Kattel, R. (2004). Governance of innovation policy: the case of Estonia. Trames, 8(4), 419. Retrieved from http://www.ceeol.com/aspx/getdocument.aspx?logid=5&id=f9ac8dc9-64b8-41d2-92f5-bc82e6446642

Keita, L. (2018). Models of Economic Growth and Development in the Context of Human Capital Investment: The Way Forward for Africa. African Development, vol 43, No. 3, pp. 159-184.

Kim, K. (2009). Adam Smith's theory of economic history and economic development. European Journal of the History of Economic Thought, 16(1), 41–64. https://doi.org/10.1080/09672560802707407

Kim, S., & Han, G. (2001). A Decomposition of Total Factor Productivity Growth in Korean Manufacturing Industries: A Stochastic Frontier Approach. Journal of Productivity Analysis. https://doi.org/10.1023/A:1012566812232

Kim, T., Maskus, E., Oh, Y. (2009). Effects of Patents on Productivity Growth in Korean Manufacturing: A Panel Data Analysis. Pacific Economic Review, 14 (2), 137-154.

King, R. G., & Levine, R. (1993). Finance and Growth: Schumpeter Might Be Right. The Quarterly Journal of Economics, 108:3, 717–737.

Klein H., & Myers M. (1999) Evaluating Interpretive Field Studies. 72. MIS Quarterly Vol. 23 No. 1/March 1999.

Knauerhase, R. (1968). The Compound Steam Engine and Productivity Changes in the German Merchant Marine Fleet, 1871-1887. The Journal of Economic History, Vol. 28(No. 3), pp. 390-403.

Konings, M. (2010). Renewing State Theory. Politics, 30(3), 174–182. https://doi.org/10.1111/j.1467-9256.2010.01381.x

Koo, J., & Kim, T. E. (2009). When R&D Matters for Regional Growth: A Tripod Approach. Papers in Regional Science, 88(4), 825–840. https://doi.org/10.1111/j.1435-5957.2009.00261.x

Koopmans, T C. (1965). On the Concept of Optimal Economic Growth. In the Econometric Approach to Development Planning, Amsterdam, North Holland.

Koutroumpis, P. (2009). The economic Impact of Broadband on Growth: A Simultaneous Approach. Telecommunications Policy, 33 (9): 471-485.

Kovalainen, E. (2008). Qualitative Research Materials. Qualitative Methods in Business Research, 78–96. https://doi.org/10.4135/9780857028044

Kreuzer, M. (2010). Historical Knowledge and Quantitative Analysis: The Case of the Origins of Proportional Representation. American Political Science Review, 104 (2), pp. 369–92

Kukk, K. (1991). On Economic and Geographical Development of Estonia in 1945-1990. In Publications of the Estonian Geographical Society V. Tallinn: Estonian Academy of Sciences.

Kukk, K. (1991). Industry. The results of Soviet economic development. In: Kahk, Juhan (Ed.). World War II and Soviet Occupation in Estonia: A Damages Report. (63–69). Periodicals.

Kumar, K., and Van Welsum, D. (2013). Knowledge-Based Economies and Basing Economies on Knowledge: Skills a Missing Link in GCC Countries. https://www.jstor.org/stable/10.7249/j.ctt5hhsh3

Kuznets, S. (1966). Modern Economic Growth, New Haven, CT: Yale University Press.

Kuznets. S. (1973). Modern Economic Growth: Findings and Reflections. American Economic Review. 1973, vol 63, issue 3, 247-58.

Lainela, S. - Sutela, P. (1994). The Baltic Economies in Transition. Bank of Finland, Helsinki

Landes, David S. (1969). The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present. Cambridge: Cambridge University Press.

Laredo, P. & Mustar, Philippe. (2001). Research and innovation policies in the new global economy: an international comparative analysis. Cheltenham: Edward Elgar

Latour, B. (1987). Science in Action. How to Follow Scientists and Engineers Through Society? Milton Keynes: Open University Press; and Cambridge, MA: Harvard University Press.

Law, J. (1987). Technology and heterogeneous engineering: the case of Portuguese expansion.

Law, J. & M. Callon (1988). Engineering and Sociology in A Military Aircraft Project: A Network Analysis of Technological Change. Social Problems 35(3), 284–97.

Lars-Hendrik, R., Waverman L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. American Economic Review, 91 (4): 909-923.

Lee, S. O., Hong, A., & Hwang, J. (2017). ICT Diffusion as A Determinant of Human Progress. Information Technology for Development, 23(4), 687–705. https://doi.org/10.1080/02681102.2017.1383874

Lee, Y. S., & Jeong, H. G. (2006). The Determinants of Economic Growth of Transition Economies: Economic Reform Versus Initial Conditions. International Economic Journal, 20(2), 241–252. https://doi.org/10.1080/10168730600699572

Levin, A., Lin, C. F., Chu, J. S. (2002). Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. Journal of Econometrics, 108 (1), 1-24.

Levine, R., & D. Renelt (1992). A Sensitivity Analysis of Cross-country Growth Regressions. American Economic Review, 82 (4), 942-963.

Levine, R. & S. J. Zervos (1993). What We Have Learned about Policy and Growth from Cross-country Regressions. American Economic Review, 83 (2), 426-430

Levine, R., & Zervos, S. (1998). Stock Markets, Banks, and Economic Growth. American Economic Review, 88:3, 537- 558.

Lewis, W. A. (1954). Economic Development with Unlimited Supplies of Labour. Manchester School 22.2:139–91.

Leydesdorff, L., & Van den Besselaar, P. (1998). Technological Developments and Factor Substitution in A Complex and Dynamic System. Journal of Social and Evolutionary Systems, 21(2), 173–192. https://doi.org/10.1016/S1061-7361(00)80004-1

Li D, Moshirian, F, Nguyen, P, & Wee T. (2007). The Demand for Life Insurance in OECD Countries. Journal of Risk and Insurance, 74:3, 637-652.

Lichtenberg, F. (1992). R&D Investment and International Productivity Differences. National Bureau of Economic Research, Working Paper No. 4161.

Lichtenberg, F. (1995). The Output Contributions of Computer Equipment and Personnel: A Firm-Level Analysis. Economics of Innovation and New Technology, 3 3-4, pp. 201-218.

Lichtenberg, F., & Van Pottelsberghe, B. (1998). International R&D spillovers: A comment. European Economic Review, Vol. 42(No. 8), pp. 1483{1491.

Lissner, W. (1985). A New School of Economic Theorists: The 'New Classical Economists'. The American Journal of Economics and Sociology, 44(2), 255-256. Retrieved April 17, 2020, from www.jstor.org/stable/3486846

Liu, C., & Xia, G. (2018). Research on The Dynamic Interrelationship Among R&D Investment, Technological Innovation, And Economic Growth in China. Sustainability (Switzerland), 10(11). https://doi.org/10.3390/su10114260

Liu, G., Liu, Y., & Zhang, C. (2018). Factor Allocation, Economic Growth and Unbalanced Regional Development in China. World Economy, 41(9), 2439–2463. https://doi.org/10.1111/twec.12572

Lucas, R. E. Jr. (1988). On the Mechanics of Economic Development. Journal of Monetary Economics, Vol. 22(No. 1), pp. 3-42.

Lumiste R., Pefferly R. and Parju A. (2008). Estonia's Economic Development: Trends, Practices and Sources, Working Paper, World Bank.

Lundvall, B.-Å., & Boras, S. (1997). The Globalizing Learning Economy. European Commission, Luxembourg, (December), 1–165.

Lundvall, B., & Johnson, B. (1994). The Learning Economy. Journal of Industry Studies, Vol. 1, pp. 23-42.

Maddison, A. (1987). Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment. Journal of Economic Literature, 25(2), 649-698. Retrieved August 19, 2020, from www.jstor.org/stable/2726106

Mahoney J. (2010). After KKV: The New Methodology of Qualitative Research. World Politics 62(1): 120-47

Mahoney, J. (2012). The Logic of Process Tracing Tests in Social Sciences. Sociological Methods & Research, 41 (4), pp. 570–97.

Maia, A. G., & Sakamoto, A. (2018). Does Wage Reflect Labor Productivity? A Comparison Between Brazil and The United States. Revista De Economia Politica, 38(4), 629–649. https://doi.org/10.1590/0101-35172018-2764

Mairesse, J., & Sassenou, M. (1991). NBER Working Papers Series R&D and Productivity: A Survey of Econometric Studies at The Firm Level.

Mankiw, N.G., D. Romer & Weil, D.N. (1992). A Contribution to the Empirics of Economic Growth. Quarterly Journal of Economics, 107, 407-437.

Markard, J & Truffer, B. (2008). Technological Innovation Systems and The Multi-Level Perspective: Towards an Integrated Framework. Research Policy, Elsevier, vol. 37(4), pages 596-615, May.

Markus, M. L., & Robey, D. (1983). The Organizational Validity of Management Information Systems. Human Relations, 36(3), 203–225. https://doi.org/10.1177/001872678303600301

Mauro P. (1995). Corruption and Growth. Quarterly Journal of Economics 110:681-712

Mauro, P. (1995). Corruption and Growth. Quart. J. Econ. 110, 3:681–712, Aug. 1995.

Mayntz, R. & Hughes, T. P. (1988). The development of large technical systems. Frankfurt: Campus.

McGuckin, R. H., Streitweiser M. L. & Doms M. (1998). The Effect of Technology Use on Productivity Growth. Economics of Innovation and New Technology, 7 1, pp. 1-26.

Mehran, M., Reza, M. (2011). A Comparative Investigation of the Relation of R&D Expenditures to Economic Growth in a Group of the Less Developed Countries and OECD Countries. Journal of Social and Development Sciences, 2 (4), 188-195.

Mesenbourg, T.L. (2001). Measuring of the Digital Economy. The Netcentric Economy Symposium. University of Maryland

Metcalfe, J. S. (1995). Economics, Organization and Management: A Review of Milgrom and Roberts. Industrial and Corporate Change, Vol. 4(No. 2), pp. 491-497.

Mia, I. (2007). The Global Information Technology Report 2005-2006. UNCTAD Expert Meeting, (December). https://doi.org/10.3359/oz0304203

Mincer, J. (1984). Human Capital and Economic Growth. Economics of Education Review 3 (3): 195–205

Molinari, B., & Torres, J. L. (2018). Technological Sources of Economic Growth in Europe and the U.S. Technological and Economic Development of Economy, 24(3), 1178-1199. https://doi.org/10.3846/20294913.2017.1280557

Montmartin, B., Herrera, M., & Massard, N. (2017). R&D Policy regimes in France: New Evidence from a spatio-temporal Analysis. 22(2017).

Moran P. (1950). Notes on Continuous Stochastic Phenomena. Biometrika, Volume 37, Issue 1-2, June 1950, Pages 17–23, https://doi.org/10.1093/biomet/37.1-2.17

Moravscik, A. (2014). Trust, but Verify: The Transparency Revolution and Qualitative International Relations. Security Studies, 23 (4), pp. 663–88.

Morgan, G., Smircich L. (1980). The Case for Qualitative Research. Academy of Management Review, 5 (4), 491-500.

Muller, A., Välikangas, L. & Merlyn, P. (2005). Metrics for Innovation: Guidelines for Developing A Customized Suite of Innovation Metrics. Strategy and Leadership, 33(1): 37–45

Mumford A. M. (1979). Problems of Estimating Lowlands Windchill, [online] https://doi.org/10.1002/j.1477-8696.1979.tb03388.x

Munnell, A. H. (1992). Policy Watch: Infrastructure Investment and Economic Growth. Journal of Economic Perspectives, 6 (4): 189-198.

Murphy, K. M., Shleifer, A., & Vishny, R. W. (1993). Why is Rent-Seeking So Costly to Growth? Amer. Econ. Rev. 83, 2:409–414, May 1993

Myers, M. D. (1997). Qualitative research in information systems. MIS Quarterly: Management Information Systems, 21(2), 241–242. https://doi.org/10.2307/249422

Myers, M.D. (2008). Qualitative Research in Business & Management. SAGE Publications

Nelson, R., & Phelps, E. (1966). Investment in Humans, Technological Diffusion, and Economic Growth. The American Economic Review, 56(1/2), 69-75. Retrieved August 20, 2020, from www.jstor.org/stable/1821269

Nelson, R. R. (1995). Recent Evolutionary Theorizing About Economic Change. Journal of Economic Literature, Vol. 33(No. 1), pp. 48-90.

Nickell, S. (1981). Biases in Dynamic Models with Fixed Effects. Econometrica, 49(6), 1417-1426. doi:10.2307/1911408

Norgaard, R.B. (1994). Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future. Routledge, London, and New York.

North, D. C. (1958). Ocean Freight Rates and Economic Development 1750-1913. The Journal of Economic History, Vol. 18(No. 4), pp. 537{555.

North, D. C. (1968). Sources of Productivity Change in Ocean Shipping, 1600-1850. The Journal of Political Economy, Vol. 76(No. 5), pp. 953{970.

Noor M. K. B. (2008). Case Study: A Strategic Research Methodology. American Journal of Applied Sciences, 5(11), 1602–1604.

OECD (1993). The Measurement of Scientific and Technological Activities: Standard Practice for Surveys of Research and Experimental Development – Frascati Manual 1993.

OECD (2019), Gross domestic product (GDP) (indicator). doi: 10.1787/dc2f7aec-en (Accessed on 13 October 2019)

OECD (2003). Technology Innovation, Development and Diffusion. OECD Environment Directorate and International Energy Agency, 4, 2–48.

OECD. (2001). Measuring Capital; OECD Manual: Measurement of Capital Stocks, Consumption of Fixed Capital, and Capital Services. OECD Publication Services, www.SourceOECD.org.

OECD. (2005). Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. 3rd edn.

OECD. (2018). Toolkit for Measuring the Digital Economy. (November), 1–123. Retrieved from http://www.oecd.org/g20/summits/buenos-aires/G20-Toolkit-for-measuring-digital-economy.pdf

Oliner, S., Sichel D. (2000). The Resurgence of Growth in the Late 1990s: Is Information Technology the Story? Journal of Economic Perspectives, 14 (4): 3-22.

Ortiz, J. M. (2009). Patents and Economic Growth in the Long Term: A Quantitative Approach. Brussels Economic Review, 52, 305-340.

Osband, K. - Villaneuva, D. (1992) Independent Currency Authorities: An Analytical Primer. IMF Working Paper WP/92/50.

Palier, B. (2005). Ambiguous Agreement, Cumulative Change: French Social Policy in the 1990s. In K. Thelen and W. Streeck (eds.), Beyond Continuity, Institutional Change in Advanced Political Economies (Oxford: Oxford University Press), pp. 127–44.

Palier, B. (2010). A long Goodbye to Bismarck? The Politics of Welfare reforms in Continental Europe (Amsterdam and Chicago: Amsterdam University Press and Chicago University Press).

Park, H. M. (2011). Practical Guides to Panel Data Modeling: A Step by Step Analysis Using Strata. Public Management and Public Analysis Program, 1–53.

Pärna, O., & von Tunzelmann, N. (2007). Innovation in The Public Sector: Key Features Influencing the Development and Implementation Of Technologically Innovative Public Sector Services in the UK, Denmark, Finland and Estonia. Information Polity: The International Journal of Government & Democracy in the Information Age, 12, 109–125. https://doi.org/Article

Peracchi, M. (2001). Convergence in per capita GDP across European regions: A reappraisal. Working Paper.

Pesaran, M. H. (2007). A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence. Journal of Applied Econometrics, 22, 265-312.

Pesaran, M. H., Smith, L. V., Yamagata, T. (2013). Panel Unit Root Tests in the Presence of Multifactor Error Structure. Journal of Econometrics, 175, 94-115.

Pesaran, M. H., Yamagata, T. (2008). Testing Slope Homogeneity in Large Panels. Journal of Econometrics, 142 (1), 50-93.

Pesaran, N. H. (2004). General Diagnostic Tests for Cross Section Dependence in Panels. University of Cambridge Working Papers in Economics No: 0435.

Pessoa, A. (2007). Innovation and Economic Growth: What Is The Actual Importance of R&D? FEP Working Papers 254, Universidade do Porto, Faculdade de Economia do Porto.

Pruulmann-Vengerfeldt, P. (2007). Participating in a representative democracy: Three case Studies of Estonian Participatory Online Initiatives. In: Carpentier, N.; Pruulmann-Vengerfeldt, P.; Nordenstreng, K.; Hartmann, M.; Vihalemm, P. (Ed.). Media Technologies for Democracy in An Enlarged Europe: The Intellectual Work of the 2007 European Media and Communication Doctoral Summer School (171−185) Tartu: Tartu University Press. (The Researching and Teaching Communication Series; 3).

Quarterly Review of Eesti Pank (1993), No. 1 and 4.

R Core Team. (2016). R: A Language and Environment for Statistical Computing. Vienna, Austria. Retrieved from https://www.R-project.org/

Ramayani, C. (2012). Analisis Produktivitas Tenaga Kerja dan Ekonomi Indonesia. Jurnal Kajian Ekonomi.

Rammel, C. & van den Bergh, Jeroen C. J. M., (2003). Evolutionary Policies for Sustainable Development: Adaptive Flexibility and Risk Minimizing. Ecological Economics, Elsevier, vol. 47(2-3), pages 121-133, December.

Ramsey, F. P. (1928). A Mathematical Theory of Saving. The Economic Journal, Vol. 38(No. 152), pp. 543{559.

Rebelo, S. (1991). Long-Run Policy Analysis and Long-Run Growth. The Journal of Political Economy, Vol. 99(No. 3), pp. 500{521.

Reinsalu, K., Winsvold, M. (2008). Does Civic Culture Influence the Use of Online Forums? A Comparative Study of Local Online Participation in Estonia and Norway. NISPAcee Journal of Public Administration and Public Policy, 1 (1), 51—67.

René K, Schot J., & Remco H. (1998). Regime Shifts to Sustainability Through Processes of Niche Formation: The Approach of Strategic Niche Management, Technology Analysis & Strategic Management, 10:2, 175-198, DOI: 10.1080/09537329808524310

Ricardo, D. (1821). Principles of Political Economy and Taxation. 3rd edn. Courier Dover Publications.

Rice, C., & Yayboke, E. (2017). Innovation-led economic growth: Transforming Tomorrow's Developing Economies Through Technology and Innovation. Retrieved from www.csis.org

Rip, A., & Kemp, R. (1998). Technological Change. Human Choice and Climate Change, 2(Vol. 2: Resources and Technology), 327–399. https://doi.org/10.1007/BF02887432

Rodrik, D. (1999). Where Did All the Growth Go? External Shocks, Social Conflict and Growth Collapses. Journal of Economic Growth. 4(4): 385-412

Rogers, E.M. (1962). Diffusion of Innovations. Free Press, New York.

Rogers, E.M. (1995). Diffusion of Innovations. Macmillan Publishers, London.

Rogers, E.M. (2003). Diffusion of Innovations. Free Press, New York.

Rogers, E.M. and Balle, F. (1985). The Media Revolution in America and in Western Europe. Ablex, Norwood.

Rohlfing, I. (2012). Case Studies and Causal Inference: An Integrative Framework Research (Basingstoke: Palgrave Macmillan).

Roiner, P. (1989). NBER Working Paper Series Increasing Returns and New Developments In The Theory Of Growth.

Romer P. (1994). The Origins of Endogenous Growth. Journal of Economic Perspectives, 8(1):3-22, https://www.doi.org/10.1257/jep.8.1.3

Romer, M. P. (1986). Increasing Returns and Long- Run Growth. The Journal of Political Economy, 94 (5), 1002-1037.

Romer, P. (1990). The Problem of Development: A Conference of the Institute for the Study of Free Enterprise Systems. The Journal of Political Economy, Vol. 98, No. 5, pp. S71-S102. University of Chicago Press.

Romer, P., Barro, R., Becker, G., King, R., Krugman, P., Meltzer, A., & Poterba, J. (1989). NBER Working Paper Seriffi Human Capital and Growth: Theory and Evidence.

Rosenberg N. (2004) Innovation and Economic Growth, Stanford University. (2004). 1–6.

Rostow, W.W. (1960), The Stages of Economic Growth, Cambridge University Press, Cambridge, UK. The World Economy, National Bureau of Economic Research, Inc, 1-34.

Rotmans, J., Kemp, R. & van Asselt, M. (2001). More Evolution Than Revolution: Transition Management in Public Policy. Foresight, Vol. 3 No. 1, pp. 15-31. https://doi.org/10.1108/14636680110803003

Saini, A. K., Jain, S. (2011). The Impact of Patent Applications Filed on Sustainable Development of Selected Asian Countries. International Journal of Information Technology, 3 (2), 358-364

Sala-i-Martin, X. (1990). Lecture Notes on Economic Growth (II): Five Prototype Models of Endogenous Growth. NBER Working Paper Series, (3564), 49.

Samimi, A. J., Alerasoul, M. S. (2009). R&D and Economic Growth: New Evidence from Some Developing Countries. Australian Journal of Basic and Applied Sciences, 3 (4), 3464-3469.

Saxonhouse, G. (1974). A Tale of Japanese Technological Diffusion in the Meiji Period. The Journal of Economic History, Vol. 34(No. 1), pp. 149{165.

Saygılı, Ş. (2003). Bilgi Ekonomisine Geçiş Sürecinde Türkiye Ekonomisinin Dünyadaki Konumu. DPT Yayın No: 2675.

Schibany, A. & Streicher, G. (2008). The European Innovation Scoreboard: Drowning by Numbers? Science and Public Policy, 35(10): 717–732

Schmid, S. K. & R. Werle (1992). The Development of Compatibility Standards in Telecommunications: Conceptual Framework and Theoretical Perspectives. In New Technology at The Outset: Social Forces in The Shaping of Technological Innovations, M. Dierkes & U. Hoffmann (eds). Frankfurt: Campus.

Schultz, T. Paul (1989). Returns to Women's Education. PHRWD Background Paper 89/001, The World Bank, Population, Health, and Nutrition Department, Washington D.C.

Schultz, T. W. (1964). Transforming Traditional Agriculture. New Haven, Conn.: Yale University Press.

Schultz, T W. (1961). Investment in Human Capital. The American Economic Review, Vol. 51(No. 1), pp. 1{17.

Schumpeter J. (1935). The Analysis of Economic Change. Review of Economics and Statistics, 17 (4); 2-10.

Schumpeter, J. (1939). Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process, New York: McGraw-Hill, Volume 1.

Schumpeter, J A. (1934). The Theory of Economic Development, Cambridge MA, Harvard University Press

Schwab K. (2016). The Fourth Industrial Revolution: What It Means, How to Respond, World Economic Forum, January 14, 2016. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

Scoville, W. C. (1951). Spread of Techniques: Minority Migrations and the Diffusion of Technology. The Journal of Economic History, Vol. 11(No. 4), pp. 347{360.

Scwartz, A. (1993) Currency Boards: Their Past, Present, And Possible Future Role. Carnegie-Rochester Conference Series on Public Policy 39.

Seawright, J., Collier, D. (2010). Glossary. In Rethinking Social Inquiry: Diverse Tools, Shared Standards, 2nd ed., ed. Henry E. Brady and David Collier, 313–60. Lanham, MD: Rowman and Littlefeld

Semmler, W., Greiner, A., & Gong, G. (2005). The Forces of Economic Growth A Time Series Perspective in collaboration with Outline. Retrieved from http://www.wiwi.uni-bielefeld.de/~semmler/cem/

Sinha, D. (2008). Patents, Innovations and Economic Growth in Japan and South Korea: Evidence from Individual Country and Panel Data. Applied Econometrics and International Development, 8 (1), 181-188.

Skare, M., & Rabar, D. (2017). Measuring Sources of Economic Growth in OECD countries. In Engineering Economics (Vol. 28). https://doi.org/10.5755/j01.ee.28.4.18502

Slater, D., & Wong, J. (2013). The Strength to Concede: Ruling Parties and Democratization in Developmental Asia. Perspectives on Politics, 11(3), 717–733. https://doi.org/10.1017/S1537592713002090

Slater, D., & Ziblatt, D. (2013). The Enduring Indispensability of the Controlled Comparison. Comparative Political Studies, 46(10), 1301–1327. https://doi.org/10.1177/0010414012472469

Solow R. (1957). Technical Change and the Aggregate Production Function. Review of Economics and Statistics, 39, August: 312-320.

Solow, R. (1994). Perspectives on Growth Theory. The Journal of Economic Perspectives, 8(1), 45-54. Retrieved August 14, 2020, from www.jstor.org/stable/2138150

Solow, R. (1997). Perspectives on growth theory. A Macroeconomics Reader. https://doi.org/10.4324/9780203443965.ch27

Solow, R. M. (1992). Policies for economic growth. De Economist, 140(1), 1–15. https://doi.org/10.1007/BF01849801

Spengler, J. (2013). Economic Factors in Economic Development. The American Economic Review, vol 47, No.2, Papers and Proceedings of the Sixty-eight Annual Meeting of the American Economic Association (May 1957), pp. 42-56

Steinlin, S. and Trampusch, C. (2012). Institutional Shrinkage: The Deviant Case of Swiss Banking Secrecy. Regulation & Governance, 6 (2), pp. 242–59.

Sukirno, S. (2015). Makroekonomi Teori Pengantar. In Makroekonomi Teori Pengantar. https://doi.org/10.1109/GLOCOM.2010.5684293

Suparmoko, M. (2016). Pertumbuhan Ekonomi, Distribusi Pendapatan dan Lingkungan. Unisia. https://doi.org/10.20885/unisia.vol28.iss57.art7

Sveikauskas, L. (2007). R&D and Productivity Growth: A Review of the Literature. Bureau of Labor Statistics Working Paper 408, Available at SSRN: https://ssrn.com/abstract=1025563 or http://dx.doi.org/10.2139/ssrn.1025563

Svensson, L. (2003). Escaping from a Liquidity Trap and Deflation: The Foolproof Way and Others. Journal of Economic Perspectives, 17 (4): 145-166.

Swan, T.W. (1956). Economic Growth and Capital Accumulation. Economic Record, Vol. 32(Nov.), pp. 334-361.

Tapscott, D. (1996). The Digital Economy: Promise and Peril in The Age Of Networked Intelligence. New York: McGraw-Hill.

Taylor, M. P. (2009). The applied economics of economic growth: Introduction and overview. Applied Economics, 41(13), 1575–1577. https://doi.org/10.1080/00036840903016613

Taylor, M., Sarno, L. (1998). The Behaviour of Real Exchange Rates during the Post-Bretton Woods Period. Journal of International Economics, 46, 281-312.

Telecommunication, W., & Report, I. C. T. D. (2010). World Telecommunication / ICT Development Report 2010.

The Conference Board (2018). The Conference Board Total Economy Database, New York. The Conference Board. [Available] from www.conference-board.org/data/economydatabase/.

Thies, C.G. (2002). A Pragmatic Guide to Qualitative Historical Analysis in the Study of International Relations. International Studies Perspectives, 3 (4), pp. 351–72.

Thirlwall, A. P. (2002). The Nature of Economic Growth. Cheltenham, U.K.: Elgar.

Thirlwall, A.P., Pacheco-Lopez, P. (2017) Economics of Development: Theory and Evidence. Palgrave-Macmillan ISBN 978-1-137-57794-8.

Todaro, M. (2000). Theories of Development: A Comparative Analysis. Economic Development.

Todaro, P. (1994). Economic Development (5th ed.) New York, London: Longman Publishers.

Toye, J., and R. Toye. (2004). The UN and Global Political Economy. Bloomington: Indiana University Press.

Trampusch, C. (2014). Why Preferences and Institutions Change: A Systematic Process Analysis of Credit Rating in Germany. European Journal of Political Research, 53 (2), pp. 328–44.

Türedi, S. (2016). The Relationship between R & D Expenditures, Patent Applications and Growth: A Dynamic Panel Causality Analysis for OECD Countries. Anadolu Üniversitesi Sosyal Bilimler Dergisi, 16(1), 39–48.

Turpin, T., Garrett-Jones, S. E., Robertson P., Charoenpanij, S & Brimble, P. (2002) Improving the System of Financial Incentives for Enhancing Thailand's Industrial Technological Capabilities, Bangkok: Thai National Science and Technology Development Agency, 2002.

Ulku, H. (2004). R&D, Innovation, and Economic Growth; An Empirical Analysis. IMF Working Papers 04/185, International Monetary Fund.

UNDP. (2001). Human Development Indicators. 1995–1997.

UNDP. (2013). Human development report 2013: The rise of the South Human Progress in a Diverse World. Technical Notice, 125, 1–8. https://doi.org/10.1016/j.rmr.2010.03.023

Usher, A. P. (1954). A History of Mechanical Inventions. 2nd edn. Cambridge (Mass.): Harvard University Press.

Uzawa, H. (1963). On a Two-Sector Model of Economic Growth II. The Review of Economic Studies, Vol. 30(No. 2), pp. 105{118.

Van Evera, S. (1997), Guide to Methods for Students of Political Science (Ithaca, NY: Cornell University).

Van Rossum, G., & Drake Jr, F. L. (1995). Python reference manual. Centrum voor Wiskunde en Informatica Amsterdam

Vengerfeldt, P. & Runnel, P. (2004) 'Uus meedia Eestis' ['New Media in Estonia'], in Vihalemm, P. (ed.) (2004).

Vu, K. M. (2020). Sources of growth in the world economy: a comparison of G7 and E7 economies. In Measuring Economic Growth and Productivity. https://doi.org/10.1016/b978-0-12-817596-5.00004-4

Waldner, D. (2015). What Makes Process-tracing Good? Causal Mechanisms, Causal Inference, and the Completeness Standard in Comparative Politics. In A. Bennett and J.T. Checkel (eds.), Process Tracing in the Social Sciences: From Metaphor to Analytic Tool (Cambridge: Cambridge University Press), pp. 126–52

Walton, G M. (1970). Productivity Change in Ocean Shipping after 1870: A Comment. The Journal of Economic History, Vol. 30(No. 2), pp. 435{441.

Webster F. (1995). Theories of the Information Society. Routledge, New York, ISBN: 978-0-415-10574-3

WEF. (2013). The Global Competitiveness Index 2012 – 2013: Country Profile Highlights. 1–17.

Wei, S., Xie, Z., and Zhang, X. (2017) China's Transition to a More Innovative Economy: Progress and Challenges. China's New Sources of Economic Growth. ANU Press. https://www.jstor.org/stable/j.ctt1trkk3v.15

Westmore, Ben (2014), Policy Incentives for Private Innovation and Maximizing the Returns. OECD Journal: Economic Studies, Vol. 2013/1. http://dx.doi.org/10.1787/eco_studies-2013-5k3trmjlhxzq

Wong, P., Ho, Y., & Autio, E. (2005). Entrepreneurship, Innovation and Economic Growth: Evidence from GEM Data. Small Business Economics, 24(3), 335-350. Retrieved August 20, 2020, from www.jstor.org/stable/40229427

Wooldridge, J. M. (2001). Asymptotic Properties of Weighted M-Estimators for Standard Stratified Samples. Econometric Theory 17, 451–470.

World Bank. (2012). World Development Report 2013: Jobs. Washington, DC. World Bank. https://openknowledge.worldbank.org/handle/10986/11843.

World Economic Forum (2006) Global Competitiveness Report 2007–2008, available at: http://www.gcr.weforum.org/

World Economic Forum. (2003). Global Competitiveness Report 2003/2004. The Global Competitiveness Report 2003-2004, 1–14. Retrieved from http://www.iese.edu/es/files/5_7341.pdf

World Economic Forum. (2010). The Networked Readiness Index 2009 – 2010 Rankings. (December 2009), 2010–2010.

World Economic Forum. (2015). The Global Competitiveness Report (Vol. 5). https://doi.org/92-95044-35-5

Yang, C., Zhao, Z., & Zhang, Z. (2017). Empirical Study of Regional Innovation Capability and Economic Convergence in China. China's New Sources of Economic Growth: Vol. 2, 229–243. https://doi.org/10.22459/cnseg.07.2017.10

Yin, Z., & Mao, H. (2013). China' s Patent Protection and Enterprise R & D Expenditure. (2001), 245–262.

Yin, Z., & Mao, H. (2017). China's Patent Protection and Enterprise R&D Expenditure. In Song L., Garnaut R., Fang C., & Johnston L. (Eds.), China's New Sources of Economic Growth: Human Capital, Innovation and Technological Change (pp. 245-262). Australia: ANU Press. Retrieved August 20, 2020, from www.jstor.org/stable/j.ctt1trkk3v.18

Zenker A. (2001). Innovation, Interaction and Regional Development: Structural Characteristics of Regional Innovation Strategies. In: Koschatzky K., Kulicke M., Zenker A. (eds) Innovation Networks. Technology, Innovation and Policy (Series of the Fraunhofer Institute for Systems and Innovation Research (ISI)), vol 12. Physica, Heidelberg. https://doi.org/10.1007/978-3-642-57610-2_12

Zhang, H. (2014). Patent Institution, Innovation and Economic Growth in China, Deepening Reform for China's Long-term Growth and Development. Canberra: ANU Press

APPENDICES

Appendix 1. Systematic literature review

No.	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
1.	**Financial sector development**	Random effect model with general to-specific sequential modelling procedure to re-examine FD-growth nexus	A well-functioning financial system is critical and has a significant effect on economic performance through enhancing the intermediation efficiency.	Awili, S., & Ahmed, A. D. (2019). Financial Openness, Trade Integration and Economic Growth: The Case of Pacific Melanesian Countries. Journal of Developing Areas, 53(4), 43–56.
2.	**Services trade liberalization**	Services trade restrictiveness is captured using a world bank index for a pooled cross-section of countries	Results suggest that services trade liberalization has a positive impact on a country's per capita GDP	Briggs, k., & Sheehan, k. M. (2019). Service trade liberalization and economic growth. Journal of developing areas, 53(4), 101–114.
3.	**Effect of financial development**	Theoretical and empirical studies are reviewed focusing on the effect of institutions and financial development	In general, indicators for financial development can be associated with the banking sector, stock market or trade openness	Hamzah, M. S., Abdullah, h., & Abdul Hamid, M. S. (2019). Economic growth, financial development, and institutions: a review of the literature. E-Bangi Journal, 16(8), 1–16.
4.	**Foreign direct investment (FDI) and preconditions - financial development, trade openness and infrastructural development**	Panel data analysis methods, namely pooled ordinary least squares (OLS), fixed and random effects with data ranging from 1996 to 2014 were used for the current study	Financial development and infrastructure development are absorption capacities which should be available in the emerging markets if economic growth is to be significantly influenced by FDI Only trade openness and infrastructural development must be available in emerging markets before FDI significantly influence growth	Tsaurai, K. (2019). Are Absorption Capacities Relevant in the FDI-Growth Nexus? Journal of Developing Areas, 53(4), 165–178.

No.	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
5.	**Effect of government consumption expenditures in D-8 countries during the period of 1988 to 2010**	Panel data method	Increasing the government consumption expenditures has a negative impact on economic growth in D-8 countries A negative impact of inflation and a positive impact of investment on economic growth	Gholami, M., & Sameei, G. (2019). The Impact of Government Spending on Economic Growth in D-8 Countries. International Journal of Industrial Mathematics, 11(3), 157–164.
6.	**Causal relationship** **Of remittance during the period 1990 - 2017**	ARDL bounds testing approach to cointegration,	While 1% increase in remittance in Indonesia will cause 0.05% increase in the economic growth at the long-run, it has 0.03% and 0.05% increase on Mexico and Indonesia economic growth respectively in the short-run with a 1% change in remittance. Remittance was found to have a 0.02% decrease on the Nigeria economy with a 1% percent increase in remittance	Odugbesan, J. A. (2019). The Causal Relationship between Economic Growth and Remittance in Mint Countries: An Ardl Bounds Testing Approach to Cointegration. Journal of Academic Research in Economics, 11(2), 310–329.
7.	**Using 37 landlocked countries, studied quality of the port infrastructure and logistics efficiency**	Structural Equation Model (SEM)	Some countries that do not have access to the sea are not, according to international agreements, inferior to other countries in terms of economic growth	Sharapiyeva, M. D., Antoni, A., & Yessenzhigitova, R. (2019). The Impact of Port Transport-logistics Infrastructure and LPI for Economic Growth: on the Example of Landlocked Countries. Scientific Journal of Maritime Research, 33(1), 63–75. Https://doi-org.portaal.nlib.ee:2443/10.31217/p.33.1.7
8.	**Effect of tourism sector in Turkey on the economy between the years of 1980-2016**	ARDL model	The effect of shock that is possible to occur in the short term within the model without constant term can be eliminated in 1/1.10 term whereas the effect of shock in the model with constant term can be eliminated in 1/1.95 term	Şik Maden, S., Bulgan, G., & Yildirim, S. (2019). The Effect of Tourism Sector on Economic Growth: An Empirical Study on Turkey. Journal of Yasar University, 14(55), 215–225.

No.	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
9.	**Financing for development and the optimal exploitation of financing resources**	Using a Vector Autoregressive framework	Both bank credit to resident private sector and government tax collections lower economic growth, while FDI promotes this growth	Awdeh, A., Jomaa, Z., & Zeaiter, M. A. (2019). Exploring the Effectiveness of Financing Resources in Promoting Economic Growth in Lebanon. Journal of Developing Areas, 53(3), 43–57. Https://doi-org.portaal.nlib.ee:2443/10.1353/jda.2019.0037
10	**Examine the relationship between financial development and economic growth for five major emerging economies: Brazil, Russia, India, China and South (BRICS) during 1993 to 2014 using banking sector and stock market development indicators.**	Examined some of the principal indicators of financial development and macroeconomic variables of the selected economies Next, using generalized method of moment system estimation (SYS-GMM), the relationship between financial development and growth is investigated	Confirm that in presence of turnover ratio, all the selected banking development indicators such as size of financial intermediaries, CDR and CPS are positively significantly determining economic growth Evidence suggests that banking sector development and stock market development indicators are complementary to each other in stimulating economic growth	Guru, B. K., & Yadav, I. S. (2019). Financial development and economic growth: panel evidence from BRICS. Journal of Economics, Finance & Administrative Science, 24(47), 113–126. Https://doi-org.portaal.nlib.ee:2443/10.1108/JEFAS-12-2017-0125
11.	**New empirical light on infrastructure's role in economic growth**	Using a semiparametric smooth coefficient model to avoid specification problems in some existing studies and admit infrastructure-induced nonlinearity and parameter heterogeneity	Telecommunications contribute to output through various sources, namely its neutral and non-neutral impacts. The total/net effect is positive but largely decreases with telecommunications stocks	Zhang, Y., & Sun, K. (2019). How Does Infrastructure Affect Economic Growth? Insights from a Semiparametric Smooth Coefficient Approach and the Case of Telecommunications in China. Economic Inquiry, 57(3), 1239–1255. Https://doi-org.portaal.nlib.ee:2443/10.1111/ecin.12770

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
12.	**Economic Complexity Index and Real GDP data were used in the analysis to determine whether the countries have a qualified export structure**	Panel Bootstrap Granger Causality Analysis.	Only one-way causality relationship from economic complexity to economic growth	Yildiz, B., & Akbulut Yildiz, G. (2019). Ekonomīk Karmaşiklik īle Ekonomīk Büyüme Arasindakī īlīşkī: Panel Bootstrap Granger Nedensellīk Analīzī. International Journal of Management Economics & Business / Uluslararasi Yönetim Iktisat ve Isletme Dergisi, 15(2), 329–340. Https://doi-org.portaal.nlib.ee:2443/10.17130/ijmeb.2019252097
13.	**Accumulation of knowledge required to produce economic value; the predictive power of years of education as a proxy for human capital started to dwindle in 1990 when the schooling of nations began to be homogenized.**	Structural equation model hat estimates a metric of human capital that is less sensitive than average years of education	Remains as a significant predictor of economic growth when tested with both cross-section data and panel data	Laverde-Rojas, H., Correa, J. C., Jaffe, K., & Caicedo, M. I. (2019). Are average years of education losing predictive power for economic growth? An alternative measure through structural equations modeling. Plos ONE, 14(3), 1–21. Https://doi-org.portaal.nlib.ee:2443/10.1371/journal.pone.0213651

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
14.	**Identify the main factors that influence the evolution of the real GDP and the GDP per capita in the EU member states**	Data panel econometric analysis	The EU level the economic growth is significantly influenced by private consumption, employment rate and net trade. Investments also have a positive effect, but obviously they need to be further supported and stimulated through effective policies. At the same time, tourism has a favorable impact on the income per capita through occupancy and the number of accommodations within this economic branch	Cristescu, A., & Tîlvăr, G. (2019). The main factors of economic growth in the European Union. Theoretical & Applied Economics, 26(3), 5–20.
15.	**Re-investigates empirically the export-led growth (ELG) hypothesis for five countries in the MENA region: Egypt, Jordan, Morocco, Tunisia, and Turkey**	Granger causality technique.	Changes in policies and regulations to improve the export sector of these countries will not ultimately pay off in terms of achieving high rates of stable economic growth in these countries	Abosedra, S., & Tang, C. F. (2019). Are exports a reliable source of economic growth in MENA countries? New evidence from the rolling Granger causality method. Empirical Economics, 56(3), 831–841. Https://doi-org.portaal.nlib.ee:2443/10.1007/s00181-017-1374-7
16.	**Evaluate the changes of efficiency in the Polish agriculture**	Stochastic parametric production function	The factors determining the development of agriculture may be divided into external (mainly changes in the regulations and agricultural policy, manifesting themselves, inter alia, in the scope and level of support for agricultural producers), and internal (efficiency changes) ones	Bezat-Jarzębowska, A., & Rembisz, W. (2016). Modelling of Efficiency Change as a Source of Economic Growth in Agriculture. Folia Oeconomica Stetinensia, 16(1), 63–74. Https://doi-org.portaal.nlib.ee:2443/10.1515/foli-2016-0005

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
17.	**Evaluate the impact of the foreign direct investments in Romania and to offer a clear image on the effects resulted from the activity of the companies with foreign capital present in Romania**	The conceptual methodological approach is correlated to a variety of references to practical actions aiming to emphasize the importance and the effects that foreign direct investment have on the trust that foreign investors have on the Romanian business environment.	The result of a qualitative analysis of the characteristics and the evolution of the foreign direct investments in Romania, emphasizing their contribution to Romania's economic growth and development, technological development, export increasing, know-how imports,	Alina, H., & Marinela, B. (2019). The Evolution of the Foreign Direct Investment in Romania and the Effect on the Economic Growth. Agricultural Management / Lucrari Stiintifice Seria I, Management Agricol, 21(2), 33–38.
18.	**Develop the theoretical linkage between culture and economic growth and empirically test the relationship by measuring culture and how it affects labor productivity**	Uses a cross-section study of developing countries and regresses economic productivity growth on a set of control variables and cultural factors	Three cultural factors, economic attitudes, political attitudes, and attitudes towards the family, affect economic productivity growth	Li, S., Park, S. H., & Selover, D. D. (2017). The cultural dividend: a hidden source of economic growth in emerging countries. Cross Cultural & Strategic Management, 24(4), 590–616. Https://doi-org.portaal.nlib.ee:2443/10.1108/CCSM-08-2016-0149

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
19.	**Investigates the sources of economic growth and relative backwardness in 10 Central Eastern European (CEE) post-socialist countries between 1995 and 2007**	Growth accounting	Primary source of economic growth was the accumulation of physical capital in the period investigated, followed by the growth of multifactor productivity	Dombi, Á. (2013). The sources of economic growth and relative backwardness in the Central Eastern European countries between 1995 and 2007. Post-Communist Economies, 25(4), 425–447. Https://doi-org.portaal.nlib.ee:2443/10.1080/14631377.2013.844927
20.	**Human Capital, Innovation and Flexibility of the Labor Force.** **Identify the problems associated with current trends in the development of new technologies**	Analysis, synthesis, induction, deduction, historical-logical method, secondary sources, and case studies	A close relationship between the creation and transfer of knowledge in the information society creates for everyone a challenge to sustain and enrich their competencies continuously. Since humans are continuously learning, human capital is constantly forming and developing	Martincová, M. (2018). Human Capital, Innovation and Flexibility of the Labor Force as a Source of Economic Growth. International Review of Research in Emerging Markets & the Global Economy, 4(1), 1222–1235.
21.	**Investigates sources of growth for Hong-Kong, the Republic of Korea, Singapore, and Taiwan**	Using the bounds testing procedure of Pesaran, Shin and Smith (2001) and the autoregressive distributed lag (ARDL) approach of Pesaran and Shin (1999)	Results emphasize that the fundamental source of economic growth is technological progress in the short run	Acikgoz, S., & Mert, M. (2014). Sources of Growth Revisited: The Importance of the Nature of Technological Progress. Journal of Applied Economics, 17(1), 31–62. Https://doi-org.portaal.nlib.ee:2443/10.1016/S1514-0326(14)60002-7

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
22.	**Estimates Cobb-Douglas production functions for Vietnam's economy using annual data in 1975–2003; measures the contribution of capital formation, labour, and technological progress to the growth of the economy, the effects of major internal and external shocks on output, the impact of economic reforms (doi moi) since the end of 1986, the rates of returns to capital and labour.**	Cobb-Douglas production functions Estimation	Technological progress was statistically absent in the growth of the Vietnamese economy throughout the study period; (2) the most important source of economic growth is capital accumulation.	Phan Minh Ngoc. (2008). Sources of Vietnam's economic growth. Progress in Development Studies, 8(3), 209–229. Https://doi-org.portaal.nlib.ee:2443/10.1177/146499340800800301

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
23.	**Role of innovative entrepreneurship in the regional economy**	Analysis is based on the methodology developed by Hermann Simon, a German scientist who has coined the term "hidden champions" describing the phenomenon of little-known successful companies that act as innovative growth engines in the German economy	Identified specifically Russian features of innovative entrepreneurship related to national cultural and historical characteristics and the current policy of import substitution	Andreeva, E. L., Simon, H., Karkh, D. A., & Glukhikh, P. L. (2016). Innovative Entrepreneurship: A Source of Economic Growth in the Region. Economy of Region / Ekonomika Regiona, 899–910. Https://doi-org.portaal.nlib.ee:2443/10.17059/2016-3-24
24.	**Explored intangible factors of economic growth; Relationship between personal capital and social capital**		Conclusions all point to the paramount place of emotional intelligence in excellence on the job	Tomer, J. F. (2003). Personal Capital and Emotional Intelligence: An Increasingly Important Intangible Source of Economic Growth. Eastern Economic Journal, 29(3), 453.
25.	**Examines the hypothesis that ICT penetration has positive effects on economic growth**	Uses the system Generalized Method of Moment (GMM) for dynamic panel data analysis to tease out the causal link between ICT penetration and growth	For the average country, the marginal effect of the penetration of internet users was larger than that of mobile phones, which in turn is larger than that of personal computers	Vu, K. M. (2011). ICT as a source of economic growth in the information age: Empirical evidence from the 1996–2005 period. Telecommunications Policy, 35(4), 357–372. Https://doi-org.portaal.nlib.ee:2443/10.1016/j.telpol.2011.02.008

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
26.	**Banks play an important role in the economy, and they constitute the main institutions of redistribution of funds.**	The methods of the scientific knowledge: abstract and logical, structural, functional, statistical ones, and comparative analysis, graphical and theoretical modeling served as the methodological basis of the research.	Need to strengthen the role of the Central Bank of the Russian Federation in the field of banking products regulation, to stimulate the creation and development of the innovative Russian banking system products and to establish a flexible financial system of the country, which should contribute to the financing and lending priorities of the socio-economic development of the country	DANCHENKO, E. A. (2014). Banking Products Market as the Main Source of Economic Growth in Russia. Financial Analytics, (32), 54–62.
27.	**To test to what extent an economic growth can be attributed to the international knowledge spillovers**	Analysis of growth accounting was based on the production function of neoclassical growth model.	The estimate supports the idea, that economic growth of European Union countries can be attributed to the international knowledge spillover, associated to the productivity increase in German economy	Zemguliene, J. (2014). The Productivity Spillovers as the Source of Economic Growth - an Empirical Analysis with European Union Countries' Data. International Multidisciplinary Scientific Conference on Social Sciences & Arts SGEM, 677–684.

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
28.	Develops a new analytical framework to account for sources of rapid economic growth in China	The traditional Solow approach is expanded to include another source of economic growth—structural change	The empirical results show that structural change has contributed to growth significantly by reallocating resources from low-productivity sectors to high-productivity sectors. It is found that the returns to capital investment in both agricultural production and rural enterprises are much higher than those in urban sectors, indicating underinvestment in rural areas	Fan, S., Zhang, X., & Robinson, S. (2003). Structural Change and Economic Growth in China. Review of Development Economics, 7(3), 360–377. Https://doi-org.portaal.nlib.ee:2443/10.1111/1467-9361.00196
29.	Propose an overall index of social exclusion and to analyze its relationship with economic growth in European countries	A three-mode principal components analysis (Tucker3 model). This method is applied to estimate an indicator of social exclusion for 28 European countries between 1995 and 2010.	The empirical evidence shows that in the short run: (1) Granger causality runs one way from social exclusion to economic growth and not the other way; (2) countries with a higher level of social exclusion have higher growth rates of real GDP per capita; and (3) social exclusion has a larger effect than income inequality on economic growth	Dell'Anno, R., & Amendola, A. (2015). Social Exclusion and Economic Growth: An Empirical Investigation in European Economies. Review of Income & Wealth, 61(2), 274–301. Https://doi-org.portaal.nlib.ee:2443/10.1111/roiw.12096

No	Technological Source	Research Method	Main Findings	Author/Research Paper Title/Date/Reference
30.	Investigates the short- and long-run causality issues among energy consumption, CO2emissions, and economic growth in Chile by using time series techniques and annual data for the 1965–2010 period.	Unit root, co-integration, and Granger-causality tests based on an error-correction model	The existence of unidirectional causality from energy consumption to economic growth, from CO2emissions to economic growth, and from energy consumption to CO2emissions. However, there was no unidirectional causality from economic growth to energy consumption, from CO2emissions to energy consumption, and from economic growth to CO2emissions. These results suggest that energy consumption can induce economic growth but not vice versa.	Joo, Y.-J., Kim, C. S., & Yoo, S.-H. (2015). Energy Consumption, Co 2 Emission, and Economic Growth: Evidence from Chile. International Journal of Green Energy, 12(5), 543–550. Https://doi-org.portaal.nlib.ee:2443/10.1080/15435075.2013.834822

Appendix 2. Chronology of key events in Estonian social system (1900 - 2015)

A Chronology of key events in Estonia (1900 – 2015)	
Date	**Event**
1918	Independence proclaimed
1920	Peace treaty with Russia signed
1934	Prime Minister Konstantin Pats leads bloodless coup and establishes authoritarian rule.
1938	Pats becomes president under new constitution.
1939	The Soviet Union compels Estonia to accept Soviet military bases.
1940 June	Soviet troops march in.
1940 August	Estonia incorporated into Soviet Union.
1941	German troops invade.
1944	Estonia reannexed by the Soviet Union. Tens of thousands of Estonians deported to Siberia and Central Asia.
1988	Popular Front campaigns for democracy. "Singing revolution" brings a third of the population together in a bid for national unity and self-determination.
1991 Independence	Communist rule collapses. Soviet government recognizes the independence of the Baltic republics.
1992	Lennart Meri becomes president.
1993	The Estonian Educational and Research Network (EENet) was created as a nationwide scientific and educational computer network to further the ICT cause. Estonia is privatised
1994	Mobile competition is introduced.
1994	Russian troops leave. Estonia joins Partnership for Peace, allowing limited military cooperation with NATO.
1996	President Meri re-elected.
1996 February	Tiger Leap programme to modernise education launched. Tiger Leap had the slogan 'one computer for every 20 pupils' and helped to provide IT facilities to schools.
1997	Estonia invited to begin European Union membership negotiations.

1998 May	The Estonian Parliament adopted the 'Principles of the Estonian Information Policy' as a roadmap for the country's development in ICTs and different programmes were created, focusing on specific areas.
2002	full-service competition is introduced in Estonia
2004 March	Estonia admitted to Nato.
2004 May	Estonia is one of 10 new states to join the EU.
2007 March	Estonia becomes the first country to allow internet voting for national parliamentary elections.
2011 January	Estonia adopts the Euro currency

Appendix 3. Socio-economic indicators - Estonia (five-year intervals) based on data from United Nations Database; ITU, OECD, Statistic Estonia, EU database

Year	2000	2005	2010	2015
Population (in million)	1,379 (2002)	1,355	1,331	1,316
Internet user per 100 inhabitants	28.6	61.5	74.1	84.2
Mobile cellular telephone subscriptions per 100 inhabitants	40.78	109.07	127.28	160.68 (2014)
Main telephone lines per 100 inhabitants	38.27	33.35	37.14	31.72
GDP per capita (at current process)	US$ 4,067	10,330	14,641	17,112
Networked Readiness Index (GITR)	23	25	25	22
Global Competitiveness Index	29 (2002)	20(2004)	35	30
Human Development Index	.78	.82	.83	.86
Freedom Index (Score: 100 reps. Max)	69.90	75.20	74.70	76.70
Poverty Rate				21.3%
CO2 emissions from fuel combustion (Mln tonnes)	15	16	19	-

Appendix 4. Average human development growth based on HDR reports.

HDI (Value)				Change in Rank (Value)	Average Annual HDI growth (%)		
Year	2000	2010	2015	2010 - 2015	2000-2010	2010-2015	1990-2015
Value	0.781	0.838	0.865	2	0.70	0.65	0.69

Appendix 5. Trend Analysis - Networked Readiness Index (NRI), 2012 - 2015 based on NRI data

TREND ANALYSIS 2012 - 2015									
THE NETWORKED READINESS INDEX ESTONIA									
		2012		2013		2014		2015	
No.	Indicator	Rank	Value	Rank	Value	Rank	Value	Rank	Value
	NETWORKED READNIESS INDEX (NRI) FOR YEAR	24	5.1	22	5.1	21	5.3	22	5.3
	ENVIRONMENT SUB-INDEX	32	4.7	31	4.7	26	4.9	23	5
	1st pillar: Political and regulatory environment								
1.1	Effectiveness of law-making bodies*	32	4.4	30	4.4	36	4.3	29	4.4
1.2	Laws relating to ICTs*	3	5.8	3	5.8	3	5.8	1	5.9
1.3	Judicial independence*	23	5.5	21	5.5	20	5.5	19	5.7
1.4	Efficiency of legal system in settling disputes*c	40	4.3	41	4.3	39	4.3	39	4.3
1.5	Efficiency of legal system in challenging regulations*c	35	4.3	39	4.2	33	4.2	23	4.3
1.6	Intellectual property protection*	32	4.8	34	4.7	31	4.8	27	4.9

1.7	Software piracy rate, % software installed	38	50	34	48	34	48	34	47
1.8	Number of procedures to enforce a contract	47	35	48	35	47	35	38	35
1.9	Number of days to enforce a contract	42	425	43	425	39	425	36	425
	2nd pillar: Business and innovation environment								
2.1	Availability of latest technologies*	34	5.9	36	5.8	25	5.8	27	5.8
2.2	Venture capital availability*	31	3.2	33	3.2	30	3.3	26	3.4
2.3	Total tax rate, % profits	120	58.6	132	67.3	114	49.4	112	49.3
2.4	Number of days to start a business	24	7	25	7	32	7	14	5
2.5	Number of procedures to start a business	28	5	30	5	34	5	23	4
2.6	Intensity of local competition*	29	5.4	25	5.5	22	5.6	29	5.5
2.7	Tertiary education gross enrolment rate, %	29	62.7	29	64.3	24	71.7	18	76.7
2.8	Quality of management schools*	48	4.6	48	4.5	54	4.5	48	4.6
2.9	Government procurement of advanced technology products*	25	4.2	35	4	34	3.9	15	4.2
	READINESS SUB-INDEX	23	5.7	24	5.6	22	5.7	22	5.8
	3rd pillar: Infrastructure								
3.1	Electricity production, kWh/capita	24	7,883.60	14	9,673.5	18	8.933.9	16	9,030.8
3.2	Mobile network coverage, % population	22	100	24	100	28	100	34	100
3.3	International Internet bandwidth, kb/s per user	43	23.1	54	24.4	62	26.5	70	29.1
3.4	Secure Internet servers per million population	25	434.4	25	532.8	23	660	18	748.9
3.5	Accessibility of Digital content*	11	6.3	11	6.3	6	6.4		
	4th pillar: Affordability								
4.1	Prepaid mobile cellular tariffs, PPP $/min.	88	0.36	85	0.35	99	0.34	98	0.35
4.2	Fixed broadband Internet tariffs, PPP $/month	59	31.52	55	29.45	61	29.07	56	29.28
4.3	Internet and telephony sectors competition index, 0–2 (best)	1	2	1	2	1	2	1	2

	5th pillar: Skills								
5.1	Quality of educational system*	42	4.3	49	4.1	47	4.1	35	4.4
5.2	Quality of math and science education*	20	5.1	19	5	26	4.9	18	5.1
5.3	Secondary education gross enrolment rate, %	17	103.6	18	103.6	13	109.1	17	107.1
5.4	Adult literacy rate, %	1	99.8	1	99.8	1	99.8	2	99.8
	USAGE SUB-INDEX	24	4.8	25	5	22	5.2	23	5.3
	6th pillar: Individual usage								
6.1	Mobile phone subscriptions per 100 population	38	123.2	24	139	12	160.4	16	159.7
6.2	Percentage of individuals using the Internet	21	74.1	23	76.5	25	79	23	80
6.3	Percentage of households with computer	32	69.2	34	71.4	31	76	29	80
6.4	Households with Internet access, %	29	67.8	29	70.8	26	75	21	80
6.5	Fixed broadband Internet subscriptions per 100 population	20	25.1	23	24.8	20	25.5	20	26.5
6.6	Mobile broadband Internet subscriptions per 100 population	19	25.9	24	42	13	76.9	17	77.4
6.7	Use of virtual social networks*	17	6.1	7	6.4	8	6.4	7	6.5
	7th pillar: Business usage								
7.1	Firm-level technology absorption*	36	5.5	34	5.5	36	5.4	32	5.4
7.27.3	Capacity for innovation*	34	3.7	33	3.8	28	4.3	31	4.5
7.4	PCT patent applications per million population	26	34.2	26	34.3	26	31.1	28	21.3
7.5	Business-to-business Internet use*g	3	6.3	15	5.9	6	6	2	6.1
7.6	Business-to-consumer Internet use*g (intro after 2012)			15	5.7	11	5.8	11	5.8
7.7	Extent of staff training*	46	4.2	46	4.2	37	4.4	36	4.4
	8th pillar: Government usage								
8.1	Importance of ICTs to government vision of the future*	13	5.7	23	4.8	18	5	12	5.1
8.2	Government Online Service Index, 0–1 (best)	18	4.9	18	0.82	18	0.82	18	0.77
8.3	Government success in ICT promotion*	27	0.5	14	5.4	13	5.5	7	5.7

	IMPACT SUB-INDEX	**15**	**5.2**	**15**	**5.2**	**13**	**5.2**	**14**	**5.3**
	9th pillar: Economic impacts								
9.1	Impact of ICTs on new services and products*	7	5.7	7	5.5	9	5.5	3	5.7
9.2	PCT ICT patent applications per million population	21	16.4	21	14.9	22	11.8	29	8.5
9.3	Impact of ICTs on new organizational models*	10	5.3	12	5.2	3	5.5	2	5.7
9.4	Employment in knowledge-intensive activities, % workforce	24	38.8	24	38.8	20	41.8	21	41.8
	10th pillar: Social impacts								
10.1	Impact of ICTs on access to basic services*	9	5.9	8	5.8	7	5.8	5	5.8
10.2	Internet access in schools*	3	6.4	2	6.4	3	6.5	2	6.6
10.3	ICT use and government efficiency*	9	5.6	10	5.5	5	5.6	5	5.8
10.4	E-Participation Index, 0–1 (best)	9	0.69	8	0.76	8	0.76	22	0.76

Appendix 6. Structure of the Estonian economy (current prices) based on BOFIT data accounted using MSP and not SNA

	1960	1970	1980	1989
Gross material product				
Industry	60.3	62.9	63.6	60.2
Agriculture and forestry	20.9	18.6	16.4	19.5
Transport and communications	3.2	3.6	3.7	4.7
Construction	8.8	9.0	8.0	8.8
Trade and other sectors	6.8	5.9	8.3	6.8
Net material product				
Industry	47.5	50.4	49.8	43.7
Agriculture and forestry	27.0	24.2	16.5	25.3
Transport and communications	3.9	4.9	4.9	6.2
Construction	8.5	8.9	9.4	10.8
Trade and other sectors	13.1	11.6	19.4	13.9

Appendix 7. Components of Estonia's technical systems

Component	Brief Explanation
DigiDoc	is a system that is widely used in Estonia for storing, sharing and digitally signing documents.
Digital Signature	enables secure, legally-binding, electronic document signing.
e-Business Register	enables entrepreneurs to register their new business online in minutes.
e-Cabinet	a powerful tool used by the Estonian government to streamline its decision-making process.
e-Law	allows public access to every piece of draft law that has been submitted since February 2003.
e-Tax	has drastically reduced the time spent by individuals and entrepreneurs on filing taxes.
Electronic ID Card	Acts as definitive proof of ID in secure electronic environments.
Mobile-ID	allows a client to use a mobile phone as a form of secure electronic ID
Mobile Payment	enables payment for goods and services using mobile phones.
m-Parking	allows drivers to pay for city parking using a mobile phone.
Electronic Land Register	a one-of-a-kind information system for storing real estate and land data.
State e-Services Portal	a one-stop-shop for the hundreds of e-services offered by government institutions.

e-Residency	Estonian e-Residency is a digital identity that allows everyone in the world to do business online with ease.
e-Police	Revolutionizes police communication and coordination for maximum effective policing
Location-based services	A positioning service that detects device location and provides information
Electronic Health Record	Integrates data from healthcare providers into national records for each patient
e-Prescription	A centralized, paperless system for issuing and handling medical prescriptions
Social Welfare e-services	Benefit system is accessible everywhere online
e-school	Allows students, teachers, parents to collaborate in the learning process
Population Register	State database for information about each person living in Estonia
i-Voting	Allows voters to cast their ballots online
Smart Grid Energy Sector	Estonian developed involving a number of cutting-edge solutions in the energy sector on smart grid
X-Road Data Layer	Allows databases to interact making integrated e-services possible

GLOSSARY

Factor - is considered as a circumstance, fact or influence that contributes to a result.

Determinant - is considered as a factor that has evidenced a causal impact on economic developments.

Growth factors in the innovation- and technology-led economy: these refer to economic growth factors in the knowledge-based economy. These are typically based on the pursuit of innovation-led growth strategies on a country level.

Research and experimental development expenditure (from here known as R&D) - The definition of R&D in the Frascati Manual (OECD, 2015) is adopted in this work. In the Manual "research and experimental development, comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D can be decomposed into basic research, applied research and experimental development.

Number of patent applications - The same OECD Frascati Manual (2015) defines patent as "an exclusive right granted (typically to an entrepreneur) for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem." The WIPO (2019) adds that, to get a patent, technical information about the invention must be disclosed to the public in a patent application.

Human capital development - the concept of human capital as used in this work is based on the OECD definition, which is defined as " knowledge, skills, competencies and other attributes embodied in individuals or groups of individuals acquired during their life and used to produce goods, services or ideas in market circumstances.

Technological Innovations - is considered in the sense of Schumpeter (Schumpeter, 1934;1939) as comprising new or significantly improved product (good or service), process, new marketing method or new organisational method; as well as normative categories described in the Oslo Manual.

Regional Innovation Capability - this concept refers to innovativeness at regional level as a consequence of networked co-operation in a regional innovation system, which sets demands for new kinds of regional innovation policy applications and economic growth rate, eventually promoting the convergence of regional economic development, in this work

Technological Infrastructure - refers to the composite hardware, software, network resources and services required for the existence, operation and management of an enterprise or organisation's IT environment. Socio-technical theorists such as Rip and Kemp (1995), refer to this as network configurations that work and are responsible for social re-configuring.

Innovation Policy - refers to the interface between research and technological development policy and industrial policy and aims to create a conducive framework for bringing ideas to market.

Technology Governance - refers to governance, i.e., the steering (controlling or guiding) between the different sectors of the development of technology at the country level. The concept is based on the notion of innovation and of techno-economic paradigm shifts according to the theories of Joseph A. Schumpeter (1934) and other scholars.

Economic Innovation - in the sense of Schumpeter (1939), economic innovation is an economic thought, which reformulates the traditional model of economic growth that drive productivity growth, so that knowledge, technology, entrepreneurship, and innovation and technological change are positioned at the centre of the model rather than seen as independent forces.

Productivity Growth - refers to shifts in the production function associated with economic innovation, where the same inputs generate a greater output; productivity rises, more goods and services are produced, stimulating wages and business profitability, in the sense of Kamien and Shwartz (1982)

Economic Growth - In the sense of Kuznets (1934), economic growth is an estimation of the value added in a country, including the total value of all goods and services, which represents growth in national income, and in the wealth of nations

Digital Economy - The digital economy is a form of social organisation in which information generation, processing and transmission are transformed into fundamental sources of productivity and power. "The knowledge-based economy" is an expression coined to describe trends in the most advanced economies towards greater dependence on knowledge, information and high skill levels, and an increasing need for ready access to all of these. Transformations in these segments (technological dimensions, spatial, economic, occupational and economic dimensions) triggered by technology are key to national development.

Technological Development - The technological or technical which include (1) establishment of computer infrastructure (2) array of innovations (3) new technologies (4) merge of IT and communications (5) use of the internet and (6) spread of information exchange between all entities must be set up to drive economic forces.

Economic Development - proportion of GDP accounted for by information business to lead to an information economy, (2) increase in information industries and (3) to chart the growth in economic worth of informational activities.

Spatial Advancement - This leads to spatial advancements which include (1) expansion of networks exponentially (2) access to satellites, databases, computer systems, etc., and (3) effect on information networks connecting locations on time and space.

Occupational Advancement - In terms of occupational advancements, when done right, the following are evident: (1) rise of an elite techno-structure, (2) preponderance of occupations in information work and (3) decline in manufacturing work and rise of service sector employment.

Cultural Advancement - These impinge on cultural advancements such as (1) extraordinary increase in information in social circulation (2) a contemporary culture (3) extensive use of digital environments (movies, podcasts, e-business), (3) a new media society or a media-saturated environment. (ITU report series)

Domestic Technology Absorptive Capacity - refers to factors such as governance and conducive business climate, technology literacy, finance of innovative firms and policy which evolve due to a country's exposure to technological frontiers, and which also yields technological progress of nations.

Innovation activities are "all scientific, technological, organisational, financial and commercial steps which actually, or are intended to lead to the implementation of innovations" (OECD, 2018).

Innovation - An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). OECD (2018:60)

SUMMARY IN ESTONIAN

Innovatsiooni- ja tehnoloogiapõhise majanduskasvu tegurite ja nende mõju uurimine Eesti majandusarengule protsessi jälgimise meetodil

Erinevates eluvaldkondades tehtud uuendused on iseäranis murrangulised ja maailma muutvad. Innovatsiooni- ja tehnoloogiapõhise majandusarengu poole pürgivad riigid peavad kõigepealt püüdma parandada majanduse põhikomponente, mis sõltuvad rohkem kui kunagi varem uue teadmuse loomisest, levitamisest ja kasutamisest. Innovatsiooni- ja tehnoloogiapõhises majanduses on teadmiste kogumine, inimkapitali arendamine ja tehnoloogiline innovatsioon majanduskasvus kesksel kohal. Eesti on alates 2000. aastast läbi teinud tohutu tehnoloogilise arengu. Seetõttu püüti käesolevas uuringus välja selgitada Eesti majanduskasvu mõjutavad tegurid ning uurida nende mõju majandusarengule alates 2000. aastast.

Uurimisprobleemi lahendamiseks ja uurimusele fookuse andmiseks sõnastati neli uurimisküsimust. Uurimisküsimusele vastamiseks kasutati protsessi jälgimise meetodit. Testimiseks püstitati seitse hüpoteesi. Uurimisprotsessi raamistamiseks töötati välja innovatsiooni- ja tehnoloogiapõhise majandusarengu kontseptuaalne mudel.

Hüpoteeside testimine näitas, et otseste ja kaudsete majanduskasvu tegurite eristamine on üheselt mõistetav ning valitud majanduskasvu tegurite, majandusinnovatsiooni, majanduskasvu ja Eesti majandusarengu vahel võib olla põhjuslik seos. Teadus- ja arendustegevuse kulud ning patenditaotluste arv ei osutunud Eesti majanduskasvus ja seega ka majandusarengus oluliseks. Samas on inimkapitali arendamine ja tehnoloogiline innovatsioon Eesti majanduskasvu määravad tegurid. Euroopa Liidus tervikuna on teadus- ja arendustegevuse kulutused, kuid mitte patenditaotluste

arv, piirkondlikku majandusarengut selgitav oluline muutuja, mis kinnitab varasemate tasakaalustamata kasvu kohta tehtud uuringute tulemusi.

Pärast olemasolevate tõendite läbitöötamist ja omavahelist kaalumist rekonstrueeriti Eesti majanduskasvu digitaalse kiirendamise kava, mis piisavalt usutavalt selgitab alates aastast 2000 Eestis toimunud majandusarengut. See kava seob Eestis digitaalse transformatsiooni läbiviimiseks kasutud strateegilised algatused ja programmid ning selgitab Eesti majandusarengu varjatud strateegiat uuritud perioodil.

Töö pakub näite protsessi jälgimise meetodi rakendamisest äri- ja juhtimisuurimustes. Järgnevad uuringud peaksid keskenduma protsessi jälgimise meetodi rakendatavusele ühe juhtumi raames. Praegu puuduvad selged juhised selle meetodi rakendamiseks ühe kaasuse raames, mistõttu järelduste tegemisel tuleb arvesse võtta teadlaste kallutatust.

Võtmesõnad: Eesti, majandusinnovatsioon, majanduskasvu mõjutavad tegurid, innovatsiooni- ja tehnoloogiapõhine majandus, innovatsioonipoliitika, protsessi jälgimine, piirkondlik innovatsioonivõime, tehnoloogia juhtimine.

CURRICULUM VITAE

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EDUCATION/ TRAINING

- **Doctor of Philosophy (PhD in Management)**
  Estonian Business School (EBS) (2015 - 2020), Tallinn, Estonia
- **CIMA Advanced Diploma in Management Accounting**
  Chartered Institute of Management Accountants, (CIMA) UK (2014)
- **Master's degree, Information Systems**
  Sikkim Manipal University (SMU), Gangtok, India (2013)
- **Bachelor's Degree, Human Resource Management**
  Valley View University, Accra, Ghana (2009)
- **Computer Networks (Network Configurations)**
  Accra, Ghana (2003)
- **Senior Secondary School Certificate**
  St. Thomas Aquinas Secondary School, Accra, Ghana (2002)

EMPLOYMENT HISTORY - Professional

- **Inventory Operations Engineer (L2), Twilio Inc.**
  Twilio, San Francisco/Tallinn, Estonia (2019 – date)
- **Product Operations Analyst, Microsoft Commerce Platforms**
  Microsoft, Redmond/Tallinn, Estonia (2016 – 2018)
- **Senior Auditor**
  National Audit Office of Ghana, Accra, Ghana (2010 - 2015)
- **Project Coordinator, FedEx Ghana**
  IAS/Fedex Ghana Limited, Accra, Ghana (2010 - 2010)
- **Project Coordinator (AGRIBIZ Exhibition & Publications)**
  Arieli Company Limited, Accra, Ghana (2009 - 2010)
- **Junior Internal Auditor (National Service Personnel)**
  Precious Minerals Marketing Company, Accra, Ghana (2008 - 2009)

- **Administrative Clerk**
  Arckycon Limited, Accra, Ghana (2002 - 2003)

EMPLOYMENT HISTORY - Academic

- **EBS MBA in Digital Society programme [IT for Business Module]**
  Estonian Business School (EBS) (2017 - 2019), Tallinn, Estonia
- **Visiting Lecturer, Business Applications of Technologies**
  Estonian Business School (EBS) (September - November 2019), Tallinn, Estonia
- **Visiting Lecturer, IT for Business and Management [Tallinn and Helsinki campuses]**
  Estonian Business School (EBS) (2016 - date), Tallinn, Estonia
- **Visiting Lecturer, Web Technologies [HTML, CSS, JS, PHP, SQL]**
  TALTECH (Tallinn University of Technology) (2017 - 2018), Tallinn, Estonia
- **Visiting Lecturer, Information Systems/Information Technology/ Logistics / Modern Organization and Management Theories**
  Euroacademy (2017 - 2018), Tallinn, Estonia
- **Visiting Lecturer, Management Information Systems**
  Estonian Entrepreneurship University of Applied Sciences [Eesti Ettevõtluskõrgkool Mainor] (2018), Tallinn, Estonia
- **Adjunct Lecturer, Advanced School of Data Studies**
  Accra Institute of Technology, Accra, Ghana (2014 - 2015)
- **Part-Time Lecturer, Management Accounting & Strategy**
  Concord Business College, Accra, Ghana (2013 - 2015)

OTHER ACADEMIC ACTIVITIES - Theses Reviews

- 2019, **Roger Allas; Anna-Kristina Vilbo; Maarja Gate,** Detecting and Reducing Digital Fragmentation Havi Estonia Example
- 2019, **Peeyush Pareek,** The role of location and community in software industry development in Estonia and its impact on the Estonian economy and society.
- 2018, **Vilma Aliisa Järvinen,** Effectiveness of a Web Channel to Increase Website Visits: Case - Quru Ltd.

- 2018, **Ville Kalle Juhani Korkeakivi,** The role of internet search engine optimization in online marketing. Case Study: Jopera Oy example
- 2018, **Saku Aleksi Laakso,** Study of free mobile games marketing practice
- 2017, **Pierre Angelo Collura,** Social media component of the evaluation of the Finnish sports sponsorship
- 2017, **Nelli Karoliina Paju,** Harju digital content usage brand creating added value: Lumene example
- 2017, **Niko Daniel Sulkakoski,** Trends video game industry: a comparative study of the company's Developer Enterprise Survival Based
- 2017, **Antti Olavi Ylitalo,** Tire Industry in India: Entering the Market

FIELD OF RESEARCH

Innovation Economics; Technological Change; Qualitative/Quantitative Research Methods; Philosophy of Science; New and Emerging Technologies; Web and internet-dependent Applications; e-Commerce.

LIST OF OTHER PUBLICATIONS

1. Boadi, Portia Opoku; Liu, Yijun; Karikari, Ama Foriwaa; **Sai, Andrew Adjah (2020).** Co-Creation and the Factors That Influence a Consumer's Willingness to Co-Create Value. *International Journal of e-Business Research*, 16 (2), 17–31.10.4018/IJEBR.2020040102.
2. Boadi, Portia Opoku; Li Guoxin; **Sai, Andrew Adjah**; Karikari, Ama Foriwaa **(2018).** Customer dissatisfaction and unfavorable word of mouth. *Human Systems Management*, 37 (4), 442–448.10.3233/HSM-18305.
3. Mousa, Mohamed; **Sai, Andrew Adjah**; Salhin, Gehad **(2017).** An Exploration for the Motives behind Enhancing Senior Banker's Level of Organizational Resilience: A Holistic Case Study. *Journal of Intercultural Management*, 9 (4), 141–163. DOI 10.1515/joim-2017-0025
4. Karikari, F. Ama; Opoku Boadi, P.; **Sai, Andrew Adjah (2017).** Rewarding employees for corporate performance improvements. *Human Systems Management,* 36 (4). DOI 10.3233/HSM-17186.
5. Opoku Boadi, Portia; Guoxin, Li; **Sai, Andrew Adjah**; Antwi, Philip **(2017).** A Critique of the Impact of Dissatisfaction on the Consumer. *Proceedings of 3rd International Conference on Social Sciences and Education Research.* China: International Conference on Social Sciences and Education Research

A Process-Trace of Selected Innovation- and Technology-Led Economic Growth Factors and Their Implications for Estonia´s Economic Development

This dissertation sought to identify economic growth determinants and explore their implications on Estonia's economic growth since 2000. Estonia had been touted as having made tremendous technological progress since 2000. Nations that aspire to an innovation- and technology-led economy must first look to improving fundamental components of the economy, which are more dependent on the production, distribution and use of knowledge than ever before. In the innovation- and technology-led economy, knowledge accumulation, human capital development and technological innovation are central to economic growth.

The root research question is: what are the determinants of economic growth and economic development in Estonia between 2000 and 2015?

Explaining-outcome process-tracing was selected as the methodology to answer the question.

To solve the research problem, four research questions were decomposed from the root research question to give the study focus. Seven hypotheses were set up for testing.

Literature was then reviewed to develop a conceptual model of innovation- and technology-led economic developments to guide the research process.

The research findings from testing the hypotheses revealed that the distinction between direct and indirect growth factors is unambiguous and that a causal relationship may exist between the selected economic growth factors, economic innovation, economic growth, and economic development of Estonia. R&D expenditure and number of patent applications turned out to not be predictors of Estonia's economic growth and therefore economic development. Meanwhile, human capital development, and technological innovation are determinants of Estonia's economic growth. For the EU region, R&D expenditure but not number of patent applications is a strong explanatory variable in the regional economic development, confirming prior studies about unbalanced growth.

The contribution of the study includes presenting an example of how to contextualize and operationalize process-tracing methodology in business and management studies.

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ISBN: 978-9949-7418-8-5

ISBN 978-9949-7418-8-5
9 789949 741885 >

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