ISM UNIVERSITY OF MANAGEMENT AND ECONOMICS

Pijus KRŪMINAS

ASSESSMENT OF THE RELATIONSHIP BETWEEN INNOVATION POLICY AND ECONOMIC GROWTH IN THE CONTEXT OF ELECTORAL INSTITUTIONS

Doctoral Dissertation

Social Sciences, Economics (S 004)

Vilnius, 2019

The doctoral dissertation has been prepared at ISM University of Management and Economics during 2013-2019, according to the doctoral right granted to Vytautas Magnus University in cooperation with ISM University of Management and Economics, Mykolas Romeris University, and Šiauliai University by the June 8, 2011 decree no. V-1019 and February 22, 2019 decree no V-160 of the Minister of Education and Science of the Republic of Lithuania.

Scientific supervisor:

prof. dr. Artūras Grebliauskas (Vytautas Magnus University, Social Sciences, Economics – S 004)

ISBN 978-9955-792-64-2

TABLE OF CONTENTS

Acknowledgement

The Road goes ever on and on, Down from the door where it began. Now far ahead the Road has gone, And I must follow, if I can, Pursuing it with eager feet, Until it joins some larger way, Where many paths and errands meet. And whither then? I cannot say (J. R. R. Tolkien, *The Fellowship of the Ring)*

Without the many people along this road the journey would not have been successful and the dissertation would not have been possible. I would like to express my gratitude to my supervisor prof. Artūras Grebliauskas for all the help, suggestions and insights during these six years, which have made me rethink not only the doctoral thesis, but gave food for thought about countless other topics. This constant cooperation has done much to help me understand research and economics.

The meetings at the ISM University's Research Department, especially, with prof. Valdonė Darškuvienė, have been the most beneficial. The several conversations with Dr Dmitrij Celov about the potential ways to explore the topics covered in the dissertation were also greatly helpful, and I would also like to thank Dr Vincentas Vobolevičius for helping me discover the fun of mathematics in social sciences. The thesis would be poorer, were it not for editing by Jadvyga and Violeta, whom I owe a debt of gratitude.

The Doctoral Studies department at ISM University of Management and Economics has been the most helpful in making sure that the studies process is as smooth as possible. I could not think of a single problem I faced. My special gratitude to prof. Ilona Bučiūnienė, who has fully supported my research during these six years, Kamilė and Monika for the crucial assistance in the final and the most strenuous stage, and all the people I have met there during my studies. My colleague doctoral students contributed to the sense of community and are an important pillar for success of anyone pursuing research

My colleagues at Visionary Analytics have always been a source of inspiration and people to look up to. Thank your constant support and encouragement.

I would like to thank my parents, Jadvyga and Viktoras, for showing that the world has much to be discovered. My sisters, Sabina and Miglė, and their families have also showed me that there is always much to learn.

Finally, my most profound gratitude to my wife, Augusta, who has been my most faithful and patient companion along this road. Without you, following any path would be mistaken.

List of Figures

List of Tables

Key terms

Composite indicator (also **index**) – a directly unobservable indicator developed on the basis of the observable simple indicators which represents a specific concept.

Effectiveness – the relevance of a policy instrument to reach the intended goals (in the given research, to increase innovativeness).

Efficiency – reaching the policy goals with a low use of resources (an efficient policy instrument achieves the same goals as an inefficient one, but with lower inputs).

Electoral institutions (also **electoral systems**) – the rules that define how citizens elect their representatives; specifically, when the distinction is made between the candidate-centred and the party list-centred systems.

Factor analysis – it aims to describe a set of variables in terms of a smaller number of factors and highlight the relationship between them. It assumes that the data are based on the underlying factors of the model and that the data variance can be decomposed into the one accounted for by common and unique factors (OECD & JRC, 2005, p. 69).

Government failure – a situation, when corrective government actions lead to market failures that are worse than the original ones (Bach & Matt, 2005), or achieve lower outcomes than could be the case.

Innovation – a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and has been introduced in the market or brought into use by the firm (OECD & Eurostat, 2018, p. 70).

Innovation activities – all developmental, financial and commercial activities undertaken by a firm that are intended to result in an innovation for the firm (OECD & Eurostat, 2018, p. 70).

Innovation output – the results of the innovation activities embodied in such outputs as research papers and patents.

Innovation policy – a set of policy instruments that affect innovativeness within a country, whether it is innovation as the main target of such policy instruments, or not (Fagerberg & Fosaas, 2014).

Innovation system – a network of institutions (e.g. universities, public and private research centres as well as policy think tanks), rules and procedures that affect the acquisition, creation, diffusion, and use of knowledge (Chen and Dahlman, 2004).

Knowledge absorption – capacities of economic agents to utilise available knowledge, ranging from basic to advanced skills and capabilities (Isaksson, 2007).

Knowledge creation – activities implemented by public or private sector agents, whose main goal is to increase the stock of knowledge.

Latent variable – the underlying factor of the model, which is not directly observable but can be measured via its results.

Linear model of innovation – the perception that the innovation activities go linearly from basic research to applied research and development, to production and diffusion (Godin, 2006).

Majoritarian electoral system – the electoral system, in which a voting district selects an individual district's representative (Milesi-Ferretti et al, 2002).

Political institutions – following Weingast's (1995) definition of constitution, the institutions that govern political decision-making which can be understood as rules governing how the policy choices are made, also in different economic systems.

Proportional electoral system – the electoral system, in which voters in a voting district contribute to selecting a number of representatives based on share of votes (Milesi-Ferretti et al, 2002).

Regionally bounded public good – good provided by policy that is usually targeted regionally (Milesi-Ferretti et al, 2002).

Simple indicator – an observable indicator used to construct a composite indicator.

Social transfer/transfer – good provided by policy, which mainly targets the specific groups of individuals, which have particular social characteristics (Milesi-Ferretti et al, 2002).

Technology transfer – acquisition of technology by domestic economic agents from foreign economic agents (Isaksson, 2007).

Abbreviations

ABM – agent-based model

ALF – active labour force

BERD – business expenditure on research and development

BES – business enterprise sector

CEE – Central and Eastern Europe

CES – constant elasticity of substitution

CGE – computable general equilibrium

DSGE – dynamic stochastic general equilibrium

EM – expectation-maximization

EU – the European Union

FDI – foreign direct investment

GBAORD – government budgetary appropriations and outlays for research and development

GDP – gross domestic product

GERD – gross expenditure on research and development

HAC – heteroskedasticity and autocorrelation consistent standard errors

IPR – intellectual property rights

JRC – Joint Research Centre

MWU – Matt-Whitney U test

OECD - Organisation for Economic Co-operation and Development

OLS – ordinary least squares

PPP – purchasing power parity

R&D – research and development

SME – small and medium enterprises

STI – science, technology, and innovation

TFP – total factor productivity

US – the United States

VAR – vector autoregression

VIF – variance inflation factors

WLS – weighted least squares

INTRODUCTION

The relevance of research. Innovation is one of the major drivers of intensive economic growth and determinants of economy's performance. This is implied both in traditional (Solow, 1956; Jones 1995) and heterodox economic theories (Nelson & Winter, 1982). It is not only that innovations can serve good for innovating firms, but they can also bring broader benefits for the society by providing the previously unavailable or highly improved products and/or processes.

However, the innovation activities are rather risky for firms, causing a market failure. Actually, without the government's intervention the level of investment in this area is likely to be sub-optimal, which has long been identified in scientific literature (Nelson, 1959; Arrow, 1962). More than that, the systemic factors may also impede the intensity and effectiveness of the innovation activities (Woolthuis, Lankhuizen & Gilsing, 2005), thus indicating the need for relevant governmental policies.

The research on the effects of the innovation policy generally shows its positive role with regard to economic development. However, the scholars also stress that these effects are not uniform. They vary depending on the level of the country's development (Falvey, Foster & Greenaway, 2006) and the functioning of the national innovation systems, which, in their turn, depend on a variety of factors, including the political ones (Fagerberg, Lundvall & Srholec, 2018). Some regions fail to fully benefit from an active innovation policy even if the investments are high (Muscio, Reid & Rivera Leon, 2015). Such variation in the performance of the innovation systems and the results of governmental intervention suggests a potential government failure in promoting the innovation activities effectively and efficiently.

The government failure in innovation policy is an important issue, since its focus on the innovation activities and creation of an innovation-friendly environment to an extent defines whether the economy will be dynamic and ready for a successful future development. Hence it is important to implement an adequate innovation policy, which would encourage the innovation activities and lead to an economic growth, as it can also promote the restructuring processes inside the economy thus making it more dynamic and adaptive to the global economic tendencies. As a result, a country's competitiveness should increase. No doubt, the innovation policy forms an significant part in any policy mix aimed to stimulate the economic growth.

Nonetheless, if government failure emerges, then the arguments supporting the implementation of the innovation policy become weaker. One of the systemic factors, which may cause such a situation, is the institutional setting defined by constitutions, whose function is to regulate how the governments may act. Therefore, it is relevant to understand the political-institutional context of a country, when analysing or designing its innovation policy. The potential harm of government failure may impede a country's economic development and innovation activities aimed at achieving the possible socially significant outcomes. The knowledge of how the governmental agents are incentivised to implement the particular policies by various political institutions, such as electoral systems, can help to identify the adequate actions meant to bring these incentives nearer to the society's preferences.

Research area and its current understanding. Current scientific literature gives special attention to public investment in R&Ds, with many scholars supporting the thesis that it positively impacts the economic growth or productivity (Minniti, & Venturini 2017; Moretti, Steinwender & Van Reenen, 2016; Bravo-Ortega & Garcia Marin, 2011). Other types of policy instruments are also considered, including tax incentives (Minniti & Venturini, 2017) and protection of the intellectual property rights (Gould & Gruben, 1996; Hammami, 2013; Hasan & Tucci, 2010). The impact of the national innovation systems on the economic growth has also been analysed (Fagerberg, Lundvall & Srholec, 2018; Fagerberg & Srholec, 2008; Freeman, 1995; Metcalfe & Ramlogan, 2008). The developed economic growth theories stress the role of the technological advancement and innovation that affect the economic growth (Solow, 1956; Jones, 1995; Nelson & Winter, 1982), thus suggesting that innovation policy can be a catalyser for growth.

The mentioned research can be categorised into three groups. The first group includes the studies that focus on the innovation policy as an instrument to correct the market failure, starting with Arrow (1962). The second group approaches the role of the innovation policy in overcoming the system failure (cf. Edquist, 2011; Edler & Georghiou, 2007). The third group focuses on the administrative aspects of policy implementation. The discussed groups cover a large share of issues related to innovation policy and its effects. However, the existing body of research provides only a limited view of the government failure (Bach & Matt, 2005), which may emerge due to the government's intervention through innovation policy. Hence there is a gap in understanding under what conditions the innovation policy operates better. Indeed, without comprehending the factors that affect the government's behaviour and the outcomes of its actions, it is difficult to understand how particular innovation policies are working in various national contexts.

Despite a rather limited theoretical focus on government failure in innovations, there are some studies addressing the role of the political institutions, including the electoral ones, in innovation policies (Batinti & Congleton, 2018; Kim, 2011). Yet, they mostly focus on the R&D investments, general spending or other areas of the economic impact of the electoral systems and other political institutions (Knutsen & Bergli, 2018; Knusten, 2011; Persson & Tabellini, 2005; Milesi-Ferretti, Perotti & Rostagno, 2002), as seen in the research literature concerning the public choice, and constitutional economics (Congleton, 2018). Meanwhile, the works on the functioning of the national innovation systems and their impact on the economic development tend to incorporate the political factors but mostly at a system-level rather than considering the specific political institutions (Fagerberg, Lundvall & Srholec, 2018; d'Agostino & Scarlato, 2014; Fagerberg & Srholec, 2008).

The existing research has approached the links between the innovation policy and economic growth and between the innovation systems, economic development and political setup of a country. However, the institutional government failure received little attention, even though the studies analysing the public choice and constitutional economics reveal that it may be relevant. Stressing the importance of innovation policy in the functioning of innovation systems, it is vital to understand whether its performance has been affected by the socially-inconvenient incentives for the governmental agents, to an extent as affected by their electoral considerations.

Research problem – what is the effect of innovation policy on economic growth, and how it varies depending on the electoral institutions.

Research object – the effect of innovation policy on economic growth in the context of electoral institutions.

Research aim – to reveal the theoretical aspects of the relationship between innovation policy and economic growth and the expected role of electoral institutions, and to propose and empirically test a model for the assessment of impact of innovation policy on economic growth in the context of such institutions.

The aim of research will be achieved by setting the following **objectives**:

1. To analyse and define the relationship between the innovation policy and the economic growth.
2. To conceptualise the expected effect of the electoral institutions on innovation policy and its link with economic growth.

3. To develop a theoretical model defining the links between the electoral institutions, innovation policy and economic growth.

4. To identify and substantiate the methods of empirical analysis relevant to approaching the research problem and develop an econometric model allowing for testing the hypotheses drawn from the proposed theoretical model.

5. To conduct the empirical research on the impact of innovation policy on the economic growth in the context of electoral institutions on the basis of the worked out model.

6. To discuss the results of the empirical analysis, their implications and further research directions.

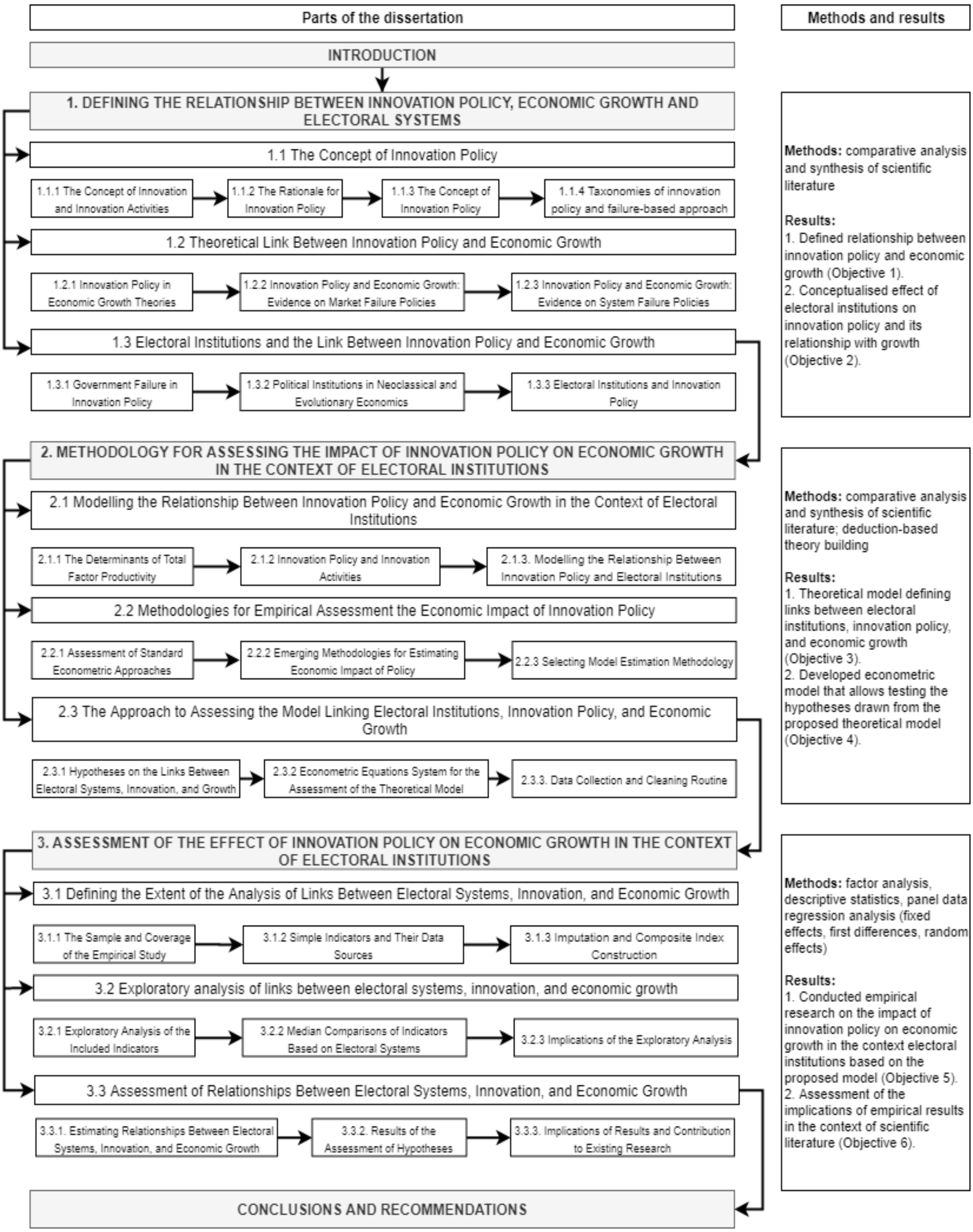
Structure of the dissertation. The structure of the dissertation corresponds to the listed objectives. The first part titled *Defining the relationship between innovation policy, economic growth and electoral systems* analyses the concept and the role of innovation policy discussed in the economic growth theories. This provides an understanding of how innovation policy can affect the economic output when complemented with the analysis of the empirical research on the topic (Objective 1). After having developed a comprehension of such links, a discussion on the potential role of the political institutions in general and the electoral systems in particular forms the last section of the first part of the dissertation (Objective 2).

The second part titled *Methodology for assessing the impact of innovation policy on economic growth in the context of electoral institutions* firstly provides a conceptual model based on the results of research literature analysis conducted in the first part of the dissertation. It specifies the links between the electoral systems, innovation policy or its outcomes, and economic output (Objective 3). Here, after having constructed the model, an assessment of the methodologies for the empirical analysis is conducted, leading to a choice of a particular strategy and development of the structure of the econometric model (Objective 4).

The third part of the dissertation titled *Assessment of the effect of innovation policy on economic growth in the context of electoral institutions* covers the initial data transformations and index calculation, the exploratory analysis of the data and panel data estimations (Objective 5). Finally, the implications of the results with regard to the scientific literature are discussed (Objective 6). This part is followed by conclusions, which sum up the theoretical and the empirical results of the carried out research.

The dissertation consists of an introduction, three parts (11 subchapters), conclusions and recommendations, references and appendixes. The length of the dissertation is 207 pages, among them, 32 tables, 9 figures and 10 appendixes are included. There are 203 entries in the list of references.

Figure 1. The Logic and Structure of the Dissertation



Research methods. The dissertation offers an analytical overview of the scientific literature on innovation policy, economic growth, the economic effects of political institutions with particular focus on the electoral systems and models linking innovation policy and economic growth also extending a considerable comparative analysis and synthesis. Based on the results of the carried out analysis, a particular model is developed by applying the deductive approach to theory-development in order to propose the theory-driven hypotheses.

The empirical analysis mainly employs factor analysis to develop the composite variables for the innovation channels and panel data analysis (i.e. fixed effects, first differences, random effects, pooled ordinary least squares and weighted least squares) to estimate the relationships between variables. In addition, the descriptive statistics methods are used to supplement the main analysis; the expectation-maximisation algorithm is used to impute the missing data values. The data is processed employing the *MS Excel*, *R* and *gretl* programmes.

Data sources. The research literature used in the thesis was accessed via a variety of academic publication repositories, including but not limited to *Springer*, *Science Direct*, *NBER: National Bureau of Economic Research*, *RePEc: Research Papers in Economics*. The quantitative data for the empirical analysis was extracted from three databases: *OECD Main Science and Technology Indicators*, *Comparative Political Dataset* and *SCImago Journal & Country Rank*.

Limitations. There are several limitations to the study. Firstly, the research has been conducted at an aggregate macro-level and some simplification of the micro processes related to innovation policy is unavoidable. This means that not all the mechanisms through which the impact of innovation policy may manifest have been reflected in the given paper in a detailed manner and it does not consider the policy instrument level. Such aggregation may hide some effects that may be interesting to analyse. Secondly, certain policies are expressed through the economic outcomes rather than specific policy actions. Such limitation comes from the limited number of indicators that can capture the intensity of policy. Therefore, to some extent, the study is bounded by indicators and their indexes, which are available for a sufficiently long time-series. Nonetheless, the outcomes allow for the identification of the economic effects of electoral institutions, which, in its turn, allows for relating them to policy-making. Thirdly, the analysis covers developed economies in order to increase the homogeneity of the sample. Therefore, the results have implications for the countries with developed economies, yet not necessarily for the developing ones. Thus future research could apply the proposed model to the latter ones. Fourthly, the empirical methods constructed for the carried out analysis are based on regression analysis, which tells more about the correlation between variables than causation. While this could preferably be improved in future research, the study uses lags which improve the model fit, suggesting that the past values of independent variables do influence the present values of the dependent variables. Hence the impact of the electoral systems is not affected by this problem, because they are time-invariant and have been adopted before the analysed period.

Defended theses. The following theses form the basis for the research:

1. Innovation activities are an important driver of the economic growth.
2. Innovation activities are subject to market and system failures, requiring intervention on the part of government.
3. Innovation systems face government failures which means that policies may vary in their effectiveness and efficiency.
4. Electoral institutions define incentives for government agents, thus affecting the scope and effectiveness of a particular policy. Therefore, electoral systems have a considerable impact on innovation policy and its interrelation with economic growth.

Scientific novelty, theoretical and practical significance of the research.

Although the given research has certain limitations, the obtained results provide new scientific insights in the field of innovation policy and economic growth:

1. The dissertation approaches the problem, which has received little attention in the former research, i.e. the role of institutional government failure in innovation policy, including its effect on policy effectiveness. The doctoral thesis sheds light on hitherto often skipped role of government failure in the area of innovation. The rules of selecting a government (i.e. electoral systems in democracies) define the actions of the politicians that are beneficial to getting into office and keeping it. By extending the nature of the innovation policy as a regionally bounded public good, the governments may manipulate spending if there are geographically divided electoral districts.
2. The paper also contributes to the discussion of the concept of innovation policy as well as geography of innovation by giving evidence that innovation policy provides goods closer to regionally bounded public goods than to social. Geography

affects the government behaviour: evidence shows that such spatial dimension is important in innovation policy. This finding may inform better policy regulation measures to help improve policy targeting.

3. The dissertation considers the moderation and mediation effects within the innovation systems, which is a rare attempt among other researchers who in most cases discuss the direct effects between the systems' elements or treat the innovation systems as a whole. The proposed theoretical model postulates that innovation policy is more relevant for the governments elected under majoritarian rules, because regional targeting helps to increase the likelihood of re-election. Since such policy mostly suits governments rather than society's agenda, despite its higher intensity, the policy is not socially effective. Greater effectiveness might be achieved when governments are elected via the proportional representation rules, because the innovation policy has less direct impact on their re-election prospects. The use of indexes in the research helped to identify the role of such specific innovation channels through which the innovation activities affect the economic growth. In contrast to the majority of research attempts, the present thesis focuses on several elements of innovation systems with both the innovation outputs and economic growth as outcome variables. Thus, the direct and indirect channels of innovation policy effects have been distinguished. It has been confirmed that such argument about effectiveness does apply to the areas of government knowledge creation and technology transfer.

4. The research results show how the electoral institutions may affect the intensity of innovation policy and its relationship with economic growth. This finding suggests that addressing the government incentives may lead to the increase of innovation policy effectiveness and its efficiency. It refers to the regulations that might put boundaries on the government's actions, thus limiting them in certain ways (e.g. focusing on subsidies vs. tax incentives), to ensure the increase of the chosen policies' benefit for the society.

Dissemination of research results. The results of research in the area of dissertation's problem have been published in the following **scientific journals**:

- Krūminas, P. (2019). Public R&D under different electoral rules: evidence from OECD countries. *Constitutional Political Economy*, 30(3), 300-329. Internet access: https://rdcu.be/bHFkx

- Krūminas, P. (2017). Innovation policy and economic development in peripheral regions in the context of electoral institutions. *Research in Economics and Business: Central and Eastern Europe*, 9(1), 48-71. Internet access: http://www.rebcee.eu/index.php/REB/article/viewFile/106/81

The results have also been presented in the following international scientific **conferences**:

- Krūminas, P. (2018). Public R&D under different electoral rules: evidence from OECD countries // poster presentation at *The Inaugural Baltic Economic Conference*, Martynas Mažvydas National Library of Lithuania, Vilnius, Lithuania, June 2018.
- Krūminas, P. (2016). Innovation policy and economic development of peripheral regions in the context of electoral institutions // presentation at *The 4th International Conference "Entrepreneurship, Innovation and Regional Development", EIRD 2016*, Tallinn University of Technology, Estonia, June, 2016.

1. DEFINING THE RELATIONSHIP BETWEEN INNOVATION POLICY, ECONOMIC GROWTH AND ELECTORAL SYSTEMS

1.1. The Concept of Innovation Policy

This chapter analyses the conceptualisation of innovation policy, as developed in the scholarly discourse. The concept of innovation policy forms the basis for the analytical approach used in the given thesis. Its first section discusses the concepts of innovation and innovation activities. The second section explores the reasons for the need for innovation policy. It concentrates on the market, system, and other failures that: a) government intervention can aim to resolve; b) government intervention creates by itself. Based on the provided classification of the reasons for its demand, innovation policy is conceptualised.

1.1.1. The Concept of Innovation and Innovation Activities

The discussion of innovation policy should begin with the definition of the concept of innovation. In economics and related disciplines, this concept became popular as late as the beginning of the 1970s (Fagerberg & Verspagen, 2009). Although, historically, the term was used well before the 20th century, its meaning was related more closely to spiritual development and renewal than to its current meaning associated with the creation of new products, processes, or knowledge (Godin, 2014b). The most obvious exception in the early use of innovation comes from Schumpeter (1939), who defined innovations as ways in which the amount of output changes alongside with the changing inputs. Innovations are mainly defined by two attributes, i.e. novelty and change (Schumpeter, 1939; Godin, 2014b). While the scientific sources tend to agree on this idea, nevertheless, their relative importance is a matter of disagreement among researchers. Some claim that innovations can be treated as any kind of change irrespective of novelty, as stressed by Winter & Nelson (1974); in such a case, they are understood as the change itself. If there are changes within an organization, they unavoidably result in innovation. Others claim that changes must necessarily bring some kind of novelty in order to be considered innovations; hence not every change operates as novel. Rogers (1998) classifies innovations according to the very source of novelty, since changes may result in the products with the new traits; the use of new resources, technology or processes; the novelty in an organisation and management, or new markets.

Despite the overviewed variety of discussions, it is assumed here that innovation must include both change and some degree of novelty, following Godin's (2014b) generalisation and Schumpeter's (1939) position. This agrees with the very concept of innovation used in policymaking, where, for instance, the Oslo Manual defines innovation as a product or process, which is both new (or improved, constituting novelty) and different (implying change) from the firm’s previous products or processes (OECD & Eurostat, 2018).

Despite the existing variation in definitions, most researchers tend to agree that an innovation process covers several stages marked by specific activities. Such innovation activities can be categorised in diverse ways. According to Fagerberg & Fosaas (2014), the broad definition of innovation activities should be focused on. In this case, they would embrace not only the creation and introduction of the product or process innovations into the market but also their diffusion within the economic system (Fagerberg & Fosaas, 2014).

Not all the scholars agree with such a position claiming that narrower definitions might be more beneficial in specific situations. An example of such a definition could be the one focusing on science, technology and innovation: (STI) provides a narrower and more specific view of innovation activities (Freeman & Soete, 2009). In this case, the scientific activities involve basic research, technology activities consider development and prototype creation, and innovation only embraces commercialisation and introduction of new products, i.e. which is the late stage of related activities. Although comparable classifications of innovation activities or public policies are sometimes used in the earlier scientific discourse, a broader definition is more frequently employed in recent research (Edler & Fagerberg, 2017).

It is important to stress that the use of the concept of innovation activities in policymaking also follows the broad definitions. The two essential documents, i.e. the *Frascati Manual* (OECD, 2015) and the *Oslo Manual* (OECD & Eurostat, 2018) agree on this. These documents identify innovation activities as embracing all the stages of science, research, technology, knowledge acquisition, training, marketing, financial, commercial and other activities, including investment in new knowledge, when technologically new or improved products or processes are adopted or planned to be adopted (OECD, 2015). The actual use of innovations is not even necessary – the abandoned or planned innovation activities are also considered as such. The latter document states that other aspects of innovation activities include disembodied technologies, know-how, the acquisition of infrastructure, marketing of innovative products, etc. (OECD & Eurostat, 2018). Therefore, the conceptualisation of innovation activities in policy prevails in the current academic discourse and focuses on the broad view discussed above..

To sum up, there are two basic approaches to the conception of innovation activities, the narrow and the broad. The given thesis employs the broad conception, since both academia and policymakers usually use the broad interpretation of innovation activities. It also covers a set of closely interrelated activities, which makes it a more consistent choice with regard to policy analysis. However, the mere existence of innovation activities does not necessarily presuppose the need for government intervention. The following section discusses why innovation activities can require government intervention in the form of innovation policy.

1.1.2. The Rationale for Innovation Policy

In order the innovation policy were pursued by governments, entities carrying out (or benefitting from) innovation activities must face challenges. They can be divided into two groups: market and system failures. Most of the traditional research on innovation policy is based on the linear model of innovation[1] and focuses on the market failure (cf. Arrows, 1962; Godin, 2006; Nelson, 1959), but later scholars of innovation policy turned their attention to systemic challenges (Borrás & Edquist, 2013; Edquist, 2011, 2001; Edler & Georghiou, 2007; Edquist and Hommen, 1999; Fagerberg & Fosaas 2014; Mazzucato, 2018; Tödtling & Trippl, 2005). Some other researchers go as far as to claim that the linear model of innovation is not viable any more (Godin, 2006) and demonstrate that data does not support it (Fagerberg, 2017). The suggestions for a new paradigm are also emerging. They stress the broader function of innovation policy than a mere overcoming market and system failures (Mazzucato, 2016) and the need to relate innovation policy to socio-technical systems (Schot & Steinmueller, 2018), yet they are still at their infancy .

Despite a rather significant attention given to market and system failures, most researchers rarely go deeper into the problem by attempting to identify other important failures in innovation activities, even though there are rare exceptions (cf.

[1] The linear model of innovation is a perception that the innovation activities go linearly from basic research to applied research and development, to production and diffusion (Godin, 2006).

Bach & Matt, 2005). This thesis distinguishes government failures as another important aspect of innovation policy. Due to the relatively low attention given to it in literature and its relevance for the present dissertation, it is discussed more in-depth than market and system failures. While these failures indicate the demand for innovation policy, government failure outlines the potential drawbacks of such government intervention. The application of the broader failure-based approach to innovation policy research should provide a more elaborate picture of innovation policy and its economic impact.

Market failure. Market failures emerge from several different problems that the market cannot solve. In the context of innovation activities, the risk of market failure may occur due to the following reasons:

- Knowledge is a public good (Arrow, 1962). It means that generated knowledge is non-rivalrous and other agents can use this resource virtually without costs. The firm that generates knowledge gains less than its competitors due to the incurred knowledge creation costs. Therefore, firms are less willing to innovate.
- Innovation activities are uncertain. Since they necessarily deal with novelty, there is always a risk that they might not lead to the expected results or may provide low returns to investment (if any). Therefore, the riskier an innovation activity, the less inclined a firm is to pursue it.

From this two closely related conclusions can be drawn. First, without government intervention, investment in innovation activities would be lower than optimal for the economy. Second, the public benefits from innovation activities are higher than the private benefits due to the public-good nature of knowledge and potential for spillovers. Therefore, government intervention correcting this market failure should be beneficial to the economy and the society in general. The policies for overcoming such a failure are also quite straightforward; therefore, this perspective is still frequently used to develop special policy instruments (Edler & Fagerberg, 2017), even if they are increasingly seen as flawed (Mazzucato & Semieniuk, 2017.

Moreover, knowledge spillovers are not necessarily harmful for an innovator. They may damage an original innovator only when their direct competitors copy the innovation, which is a rare occasion (Metcalfe, 2003). Otherwise, a copied innovation is used in a different segment of the market, the innovator retaining its competitive advantage in its own market segment. Knowledge spillovers among the non-competing firms may be beneficial to both the innovator and the copier because they can find a mutually beneficial cross-sector usage of the generated knowledge. Such spillovers may also increase social benefit.

System failure. The innovation systems approach focuses on another type of failure (Edquist, 2001; Tödtling & Trippl, 2005; Woolthuis, Lankhuizen & Gilsing, 2005; Schot & Steinmueller, 2018). An innovation system can be understood as a network of institutions (for example, universities, public and private research centres as well as policy think tanks), rules and procedures that affect the acquisition, creation, diffusion and use of knowledge (Chen and Dahlman, 2004). While the market failure approach is based on the linear model of innovations, contrariwise, the system failure approach stresses the non-linearity and complexity of innovation activities. Rather than focusing solely on the linear link from basic research to market diffusion, the innovation systems approach takes into account the importance of the agents' behaviour, institutional environment and interaction networks. Hence it is closer to the above-mentioned market failure interpretation provided by Metcalfe (2003) than to the one that comes from Nelson (1959) and Arrow (1962).

Due to its more complex view, the innovation systems approach identifies a greater variety of the specific failures related to innovation activities (Bach & Matt, 2005). A possible taxonomy distinguishes the following types of system failure: the infrastructural failure, the contract failure, the path-dependence dead-end, the hard and soft institutional failures, the strong and weak network failures and the lack of opportunity (Woolthuis et al., 2005). However, for the purposes of the current research, such detailed categorisation is not necessary due to the danger of making the research overcomplicated.

The lack of a single commonly accepted classification of system failures makes it more difficult to analyse the system failure as a uniform concept. Nonetheless, it is clear that different types of innovation policy are required to solve system failures than to solve market failures: the analysis cannot be limited to subsidies or protection of the intellectual property rights (Edler & Fagerberg, 2017). The focus on the different types of failure would also provide a more complex view of innovation policy than before. In addition to minimizing the market-related risks faced by an innovating firm, governments must take into account and correct the environmental and behavioural factors to ensure that the policy reaches its goals.

Government failure. The third type of failure emerges when the government intervenes seeking to correct the market or system failures. While research on the market and system failures tends to focus on the behaviour of economic agents, government failure, in its turn, covers the actions of entities that should correct the latter types of failure. Thus, government failure directly affects the effectiveness and efficiency in overcoming the market and system failures. Unfortunately, despite its obvious importance, government failure is usually given much less attention even in the textbooks in economics (Fike & Gwartney, 2015). Therefore, this issue requires additional attention not only for understanding why and how government failures emerge but also how to limit them and their effects.

Government failure is closely related to the agency problem. In this respect, the government can be seen as a subject-agent, whose task is implementation of certain policy preferred by the society-principal. However, the preferences of a principal and an agent may be aligned not perfectly, and the society may not be able to fully control the government due to the limited control mechanisms and limited knowledge. Moreover, the government may be inept and unable to implement policies effectively or efficiently, but the society may lack knowledge or adequate instruments to change the government. Such limitations faced by the society enable governments to seek their own goals and allow for the government failure to emerge.

Government failure emerges when the government policies employed to correct other failures create negative effects by themselves. As in the case of system failure, different taxonomies are possible. Reszketo (2008, as discussed in Tomescu & Stanescu, 2009) provides the following typology of government failures: the fundamental-informational failures that emerge due to imperfect information held by the government; institutional failures that occur due to institutional organisational constraints confronted by the government entities and motivational failures that emerge due to the government agents having their own agenda, not necessarily coinciding with societal benefits.[2]

On the other hand, Bach & Matt (2005) list three reasons for government failure that somewhat differ from the typological scheme offered by Reszketo (2008, as discussed in Tomescu & Stanescu, 2009). As it is clear from their work, the reasons

[2] This point relates to the principal-agent problem, where the principal is the government, particular government entities or agents.

are as follow:

- Misidentified failure situations. Even when identification is correct, the government does not have sufficient information about the specific steps that it should take and the needed intensity of the enacted policies.
- Interest group lobbying for the policies that are optimal for their support base but not for the whole economy or society. Therefore, government intervention might lead to the outcomes that are not optimal for the society.
- State intervention might have negative impacts because it creates asymmetry in the provision of benefits, thus distorting competition.

Although the two presented typologies of government failure may appear diverse enough, they do share similarities. The first type of government failure is similar in both taxonomies and relates to imperfect information. The second type of failure within the framework of Bach & Matt (2005) is associated both with institutional and motivational failures which are presented in the classification worked out by Reszketo (2008, as discussed in Tomescu & Stanescu, 2009). Finally, the third type of failure in Bach & Matt's (2005) taxonomy concerns the problems of market distortion and benevolence of the government as listed by Reszketo (2008, as discussed in Tomescu & Stanescu, 2009). Thus, to sum up, the two taxonomies are found as closely interrelated; however, Reszketo (2008, as discussed in Tomescu & Stanescu, 2009) offers a clearer and better-structured approach. In both cases, the agency problems persist either due to the incompetence of government agents or misalignment of preferences as discussed above.

It important to stress that government failure exists in all three areas of government intervention, innovation policy making no exception (Martin & Scott, 2000). For instance, subsidising the innovation activities of the specific firms or economy sectors may lead to subsidising the inefficient ones, or to competition distortion. This may enhance the competitive advantage of the inefficient firms and hurt the competitive ones that are, actually, not subsidised. It shows that government intervention can lead to the socially negative outcomes. It may be applicable as well when the investment is based on particular regions, or when certain interest groups push for an increase in public support to the specific innovation activities that do not bring the highest level of return on investment to the society. All of this creates a trade-off between the positive effects of innovation policy and the negative ones, but mainly benefits specific stakeholders.

In the case of misidentification, the choice of which firms should be supported might serve as a good example. Due to asymmetric information, the firms may hide their disadvantages while at the same time signalling their advantages, thus creating the principal-agent problem. As a result, governments may support the firms that do not bring the best results. In the case of asymmetric benefits, the scholars point out an example related to patenting. While patents might encourage the innovative activities on behalf of the firms, it would bring price distortions through creating a government-supported monopoly of patented innovations (Angeles, 2011; Bach & Matt, 2005).

On the one hand, the existence of the market and system failures serves as a rationale for government intervention. On the other hand, government intervention may potentially do less to overcome these failures than to increase their negative impacts. Likely, the government failure would imply that the policy would be a mix of both benefits and drawbacks. Nevertheless, as long as the positive effects outweigh the negative ones, the policy turns to be fruitful, even if it could be more efficient. And the existing evidence suggests that despite the risk of government failure, governments should implement innovation policy (Martin & Scott, 2000).

In the case of innovation policy, informational failure might mean that a government will adopt a non-optimal policy because it does not have the information required to make such decisions. Institutional failure can emerge due to the lack of government agents' skills to implement the proper instruments of innovation policy that could be most effective and efficient in promoting the innovation activities or improving an innovation system. Finally, motivational failure might mean that the government agents are not intervening in a way which would provide the best results. Instead, they try to maximize their individual gains. In this case, the institutions may also play an important role. For example, the electoral systems define how the government agents have to act in order to remain in a power position (i.e. impact the adequate strategies to receive enough votes to maintain power). Consequently, the motivation of the politicians as such depends on these institutions.

Despite the factor of government failure being acknowledged, it still attracts relatively little attention on the part of researchers in economics, which is seen with regard to the subfield of the economics of innovation as well. The available papers mainly focus on theorising and are rare attempts thus forming a considerable gap in the field of social studies: there remains a strong rationale for governments to develop innovation policy. The conception of entrepreneurial policymaker clouds the relation between the potential risks and policy implementation, and here a more realistic assessment is needed. Therefore, the present thesis focuses on the analysis of government failure in innovation policy, attempting to eliminate the existing gap and thus extend current research by its contribution.

Market and system failures provide a rationale for government intervention. However, it may lead to negative outcomes due to government failure. Still, the situation might be corrected if the potential for government failure were acknowledged and its drivers identified. Since there are different types of failures related to the innovation activities, the following two sections are introduced to define the concept of innovation policy and discuss what instruments can be used to overcome different failures and how effective they are.

1.1.3. Defining the Innovation Policy

The market and system failures suggest that a particular innovation policy is needed. Obviously, they presuppose the need for differing policy instruments. Therefore, it is not surprising that the conception of what innovation policy actually is and what it should entail has been fluid over time, leading to a variety of definitions. However, such varying concepts, tend to follow a particular historical timeline, where innovation policy keeps being increasingly understood as a complex non-linear phenomenon rather than a set of instruments that might be employed to correct problems in the linear process of innovation.

There are three stages in the evolution of the perception of innovation policy distinguished by the linear, the system, and the holistic approaches. The linear model of innovation policy emerged with the concept of science policy and its extension to science and technology policy in 1950s-1970s (Bryant, 2001). The linearity comes from the model of innovation activities depicted as an orderly process, which links the connected stages of research, prototype creation, and commercialisation. It was argued that public investment in research activities, which have commercial potential, should solve the market failure and increase the innovativeness of the firm. This view did not take into account the systemic issues related to innovation activities, such as cooperation, networks, etc. Nonetheless, it provided important insights and improved the understanding of innovation policy (Godin, 2006), which was built-upon in the later stages. The linear model was also used to inform policymaking and led to the creation of innovation indicators which are still widely used.

A new approach to innovation research emerged in 1980s. Its proponents focused on the systemic aspects of the innovation activities, resulting in the construction of the innovation systems' framework, which gained much attention (Freeman, 1995; Lundvall, 1992, 2007; Chaminade, Lundvall, & Haneef, 2018) and is still widely used. During this period, the innovation scholars started concentrating more on the national and regional aspects of innovation actions: they analysed agents' networks and their interaction. Innovation policy was treated as a broader issue than merely R&D expenditure, R&D tax incentives, or other instruments used to correct the market failure. The systemic view also covered the policies that regulated the environment of the innovating agents and the institutions which affect their behaviour. The innovation systems approach inspired the exploration of the innovation activities at multiple levels (e.g. national and regional). Such a varying focus illustrates the significance of the impact of environment on the innovation activities (cf. Rodríguez-Pose & Crescenzi, 2008).

The holistic concept of innovation policy includes the elements coming from the different fields of public policy that might not necessarily focus directly on the innovation activities. While the linear and the systemic views of innovation policy focus on such policies, the holistic view, in its turn, also gives centres on the policies that do not specifically focus on the innovation activities, but include education, trade, industrial and other policies due to their impact on innovation systems (Bryant, 2001). It is worth noting here that the holistic approach is stronger in the academic discourse rather than in practical policymaking (Edquist, 2014). However, it naturally follows from the implications of the systemic view of innovation (Edler & Fagerberg, 2017). However, the new perspectives in policy making, such as mission-orientation (Mazzucatto, 2016; 2018), are pursued by the European Commission in planning the future research-funding activities.

The discussion on the innovation policy can also be centred on the dichotomy between the narrow and the broad approaches. The broad definition of innovation policy describes interprets it as a set of policy instruments that affect the innovativeness within a country. The narrow definition of innovation policy involves only those policy instruments that are developed with the specific purpose of affecting the innovation activities and do not consider agent interaction. According to Fagerberg & Fosaas (2014), the broad conception has an advantage over the narrow one in that it allows the scholars to include more factors in their research. It enables the more in-depth modelling and more precise representation of reality. It is especially fruitful, when the economic effects of the innovation activities are analysed due to the importance of the spread and diffusion of innovations, their impact on learning and deeper changes that they create.

The rationale for innovation policy (i.e. market and system failures), challenges in its implementation (i.e. government failure) and the evolution of innovation policy (i.e. the linear, systemic, and holistic views) seem to correspond with the broad conception given above. It involves more than just a linear understanding of the policies targeting, solely or specifically, at innovation activities. Different failures require different kinds of policy instruments, some of which do not fall within the scope of the narrow linear model of innovation policy. Here trade, foreign direct investment and other areas can serve as examples, where government actions would not fall under the scope of the narrow linear model of innovation policy, despite their effects on the innovation system.

After having discussed the evolution of the concept of innovation policy, it is obvious that its scope is broader and does not limit to the aspects of science and technology policy (Edquist, 2001) and therefore its instrumentarium is found to be more complex than merely subsidies or IPR protection (Edler & Fagerberg, 2017). Many scholars hold a similar position. For example, although focusing on technology diffusion, Kraujelytė & Petrauskas (2007) agree that innovation policy should be directed toward other policy areas and embrace more aspects, factors than technology diffusion. Tödtling & Trippl (2005) argue that the broad conception of the innovation activities is crucial in designing a suitable policy. The R&D spending is not a miraculous remedy, and policy should deal with the systemic issues (i.e. include the growth of human and social capital). Otherwise, the investment in R&D may simply lead to wasted resources, especially in less advanced economies (Muscio, Reid & Rivera Leon, 2015; Oughton, Landabaso & Morgan, 2002).

The overlapping of the broad and narrow concepts of innovation policy can be related to the vertical (i.e. through particular activities) and horizontal (i.e. covering a variety of policy areas, such as industrial policy) policy projections (Karo, 2011). It could be argued that here, the linear view is possible insofar as it is used to examine some sub-area of innovation policy, such as R&D investment. However, even in this case, its applicability may be limited due to the importance of the interactions and synergies in the policy mix.

It should be maintained that the contrast between the broad and narrow conceptions of innovation policy may also emerge from the very definition of the innovation policy goals. On the one hand, the narrow aim of innovation policy may be interpreted as diminishing the unwillingness of the private sector to invest in innovation activities (cf. Vilys, Jakubavičius & Damkus, 2008). Such conception is closely related to the market failure as defined by Arrow (1962). On the other hand, innovation policy may have a broader goal that takes into account network creation, stimulation of agent cooperation in addition to solving the problem of underinvestment (Hofer & Polt, 1998, as quoted in Bryant, 2001).

In order to ensure a broader reflection of innovation policy in this thesis, the relationship between the economic growth and innovation policy is discussed not only in the context of market failure, but also taking into account the system and government failures. For this reason, the thesis employs the broad conception of innovation policy.[3] The broad definition of innovation suits the purposes of the present study better than the narrow conception. Since innovation policy unavoidably encounters a variety of failures, the linear model that includes the policy instruments, such as R&D investment, does not prove sufficient for developing an innovative economy.

In their analysis of different types of failures, the scholars approach innovation

[3] Some researchers do not tend to use the overarching term of innovation policy but split it into smaller separate segments. Others employ a more expanded term *science, technology and innovation policy* (cf. Kuhlmann & Edler, 2003; Lundval & Borrás, 2005). The use of such terms as *research and development policy* (Tassey, 1997), *technology policy* (Metcalfe, 1995), *science and technology policy* (Bach & Matt, 2005) have also been noted. It should be observed that, in fact, the mentioned terms join the terms used to analyse various stages of innovation creation. Therefore, their employment partly depends on the objectives of the carried out research. However, this is not always the case, and different terms are used as synonyms to represent the broad conception of innovation policy. For example, Kuhlmann (2001) and Metcalfe (2003) use the terms of *research, technology and innovation*, *technology policy* and others interchangeably. Despite such inconsistency in terminology, the bibliometric analysis shows that the terms *innovation studies* and *innovation* are becoming dominant (Fagerberg & Verspagen, 2009). In the terminology of Fagerberg & Verspagen, the term *innovation studies* is most closely related to the field of economics, while other concepts are more closely related to other disciplines. Such findings further support the choice for the use of the term *innovation policy* in the given thesis which allows for its broad interpretation.

policy from the two theoretical perspectives, namely, the neoclassical and evolutionary-structuralist frameworks. The neoclassical framework deals with the market failure and perceives innovation activities as the linear ones. According to it, the state should act so as to solve the formed market failures. While there are reasons for the demand for government intervention, the followers of this view perceive innovation policy in a limited way. Meanwhile, the evolutionary-structuralist framework embraces the evolutionary, system- and knowledge-based approaches (Bach & Matt, 2005). One of its most important differences from the neoclassical approach is that the evolutionary-structuralist perspective stresses the impossibility of market equilibria. Contrariwise, innovation activities are dynamic by their nature. Thus this view reflects the broad conception of innovation policy.

To an extent, the neoclassical and evolutionary-structuralist frameworks overlap regarding some policy instruments (e.g. public investment in R&D). However, policy interpretations differ. The proponents of the neoclassical framework would argue that such policy is necessary to reach the socially beneficial market equilibrium. Meanwhile, the proponents of the evolutionary-structuralist framework would stress that the very concept of market equilibrium is irrelevant[4] and, while public R&D spending may be beneficial, it is not due to the achieved market equilibrium (Schröter, 2009). To sum up, both camps might argue about the demand for the policy instruments with the similar short-term objectives, even if the perceived long-term goal would differ. In the neoclassical approach, the final goal would be the market equilibrium, while in the evolutionary-structuralist approach there would hardly be any final common social goal.

The following section focuses on policy implementation and the policy instruments that might be employed. This discussion provides a more substantial content to the examined concepts of innovation policy, leading to the further identification of this thesis in the context of scientific debate.

1.1.4. The Taxonomies of Innovation Policy and the Failure-Based Approach

There are several dominant classifications of the innovation policy

[4] Evolutionary economics see economic growth as an evolutionary process that does not have a predefined trajectory but rather depends on the evolution of innovation, technology and industry (Witt, 2008).

instrumentarium. Table 1 provides a typology proposed by Greenhalgh & Rogers (2010), listing four types of instruments used in the linear innovation policy. Consider:

Table 1. An example of innovation policy typology

Policy	Purpose
Government subsidies	Funding basic research that is still far from commercialisation. It is often required that outputs of the basic research would be published as an open source and their copying would create low marginal costs. Therefore, government subsidises the creation of a public good.
Government support for a 'club'	Funding innovation activities that are carried out by several firms. These firms get the benefits which are private; hence pure public good is not created.
Pigouvian subsidies	Funding the transfer of benefits from the innovation activities to society and the economic agents other than the original innovator. This increases both private and social benefits. In this case, the R&D activities are subsidised, if they are directly leading to the commercialisation of the products (contrary to the government subsidies that focus on basic research), consequently reaching market equilibrium.
Regulation of property rights	Following Coase (1937), such policy allows to introduce usually non-taxable externalities to the market and provide more incentives for the economic agents to carry out the innovation activities that also lead to market equilibrium.

Source: based on Greenhalgh and Rogers (2010)

Such taxonomy is abstract enough and can be used for the comparison of various countries at a macro-level. Moreover, this classification embraces a wide policy spectrum ranging from the direct government investment in innovation activities to the intellectual property rights (IPR) protection. Nonetheless, the listed instruments are mostly aimed at a mere fixation of the market failure.

Innovation policy can also distinguish between the supply-side and demand-side policy (Edler & Georghiou, 2007; Edler, Gök, Cunningham & Shapira, 2016). Employing this approach, Edler & Georghiou (2007) propose a more detailed and multi-layered taxonomy of innovation policy. At the first level, the employed instruments are determined by the supply- or demand-side innovation policy. The supply-side innovation policy is related to increasing the incentives for the private sector, which allow investing in the innovation activities and, consequently, lowering the costs for the innovating firms. Such policy includes adequate financial instruments[5] and services[6]. The demand-side innovation policy is a set of policy instruments that create demand for the new products, technologies, processes, or services[7]. This taxonomy is much more detailed than the two discussed above and it can be further cross-mapped with the goals of particular instruments (Edler et al., 2016). Nonetheless, this classification is more beneficial, when innovation policy is assessed in a smaller sample of countries and the focus lies on the separate policy instruments rather than their combination.

It is also possible to distinguish between the financial and non-financial instruments of innovation policy and the consequent subdivision of these categories in the following way: the instruments of public distribution of goods and services, the modification of the market stimuli and support for the market improvement mechanisms (in the latter, only financial instruments are found) (Vilys et al., 2008). The use of these two dimensions allows for a more varied analysis of innovation policy. Nevertheless, it should be stressed that such classification is more beneficial for the analysis of the innovation policies applied in the specific countries than for the comparison of the types of innovation policies across countries.

Despite a variety of innovation policy classifications, the dominant one is the distinction between the regulatory instruments, economic and financial instruments, and soft instruments (Borrás & Edquist, 2013). The first category encompasses all the policy tools that regulate the market and social interactions. The second one contains the economic and financial instruments that may either increase or diminish the incentives to carry out specific innovation activities. The third category of soft instruments concerns the non-binding ones (e.g. codes of conduct, recommendations, etc.). However, they may contribute to the effectiveness and efficiency of the innovation activities. This taxonomy covers many subtypes of innovation policy and therefore is rather exhaustive. Yet, it does not allow to fully assessing how innovation policy can address the failures listed above. Table 2 given

[5] Such as increasing equality, fiscal policy, subsidies to public sector innovation activities, subsidies for mobility and learning, subsidies to private sector innovation activities.

[6] Such as information diffusion and mediation, networking instruments.

[7] Such as systemic policy (e.g. supply-chain policies), regulation by defining goals of innovation activities, public procurement and increasing private demand for innovation through tax regulation, demand subsidies and other policies.

below summarises the classification of various taxonomies and their relation to the discussed concepts of innovation policy.

Table 2. Taxonomies of innovation policy

Conception	Scientific framework	Taxonomy	Authors
Narrow	Neoclassical	Government subsidies, Pigouvian subsidies, club support and property rights management	Greenhalgh & Rogers (2010)
		Public service provision, modifying market stimuli, enhancing market mechanisms. Financial and non-financial instruments	Vilys, Damkus & Jakubavičius (2008)
		Substituting supply-side and demand-side policy, information provision, diminishing externalities	Bach & Matt (2005)
Broad	Evolutionary-structuralist	Three-type (regulatory, economic-financial and soft instruments)	Barras & Edquist (2013)
		Instruments targeting the systemic problems and government failure	Bach & Matt (2005)
		Supply- and demand-side policies	Edquist & Gheorghiu (2007)
		Provision of knowledge inputs, demand-side activities, provisions of constituents for innovation systems, support services for innovators	Edquist (2011)
		Orientation (supply- and demand-side) and goals (increased R&D activities, skills, access to expertise, systemic capabilities, demand for innovation, better framework, better discourse)	Edler, Gök, Cunningham & Shapira (2016)

This chapter shows that there is no single interpretation of innovation policy and reasons for its demand. Current research gives its main attention to the market and system failures, while government failure has been little discussed. This constitutes a gap in knowledge, since the identification of government failures might increase the probability that innovation policy will be successful. The discussion extended in this chapter covers a broad variety of topics related to innovation policy. They range from the problem of conceptualisation to the reasons for the demand for such policy. Table 3 cross-maps the specific failures that innovation policy attempts to solve and policy instruments that can help overcome the problems in order to conceptualise the innovation policy framework for the purposes of this thesis.

Table 3. Failure-based approach to innovation policy

	Market failure	**System failure**	**Government failure**
Reasons for intervention	Unwillingness of business to invest in innovation activities due to high risk and knowledge spillovers.	Path-dependence dead-end Unsuitable infrastructure Inefficient institutions Undeveloped networks Lack of opportunity	Government fails to intervene successfully and has a negative impact on innovation activities
Objectives of policy	Increasing innovation activities in the private sector.	Strengthening agent cooperation Modifying institutions Drawing new development paths	Diminishing negative effects of policy intervention
Subjects of policy	Public and private organisations.	Public and private organisations, institutions.	Institutions
Policy instruments (following Edquist, 2011)	Provision of R&D results (creation and provision of knowledge to organisations). Forming of new product markets Incubation activities Financing of innovation activities Provision of consultancy services	Competence building (individual and institutional learning) Creating and changing of organisations Networking through markets, or other mechanisms Creating and changing institutions	Creating and changing institutions
Scope of analysis	R&D subsidies, intellectual property rights protection, R&D taxation incentives	Components of innovation systems	Institutional environment influence on innovation policy

Following the discussed conceptual approaches to innovation policy, it is clear that a coherent and elaborate analysis of the impact of innovation policy on economic growth should be located within a framework broader than the neoclassical one. In the given case, the evolutionary-structuralist view seems to be the most promising and reconcilable with the latest advances in the research concerning the economic impacts of innovation policy. The analysis has also revealed that innovation policy can be conceptualised through the specific failures it attempts to solve. They include government failures which pose the problems to the policymakers and the society. Wrong institutions can make innovation policy less effective.

1.2. Theoretical Link Between Innovation Policy and Economic Growth

Innovation policy targets and promotes the innovation activities in a country, while the outcomes of innovation policy may be both economic and social. Although economic growth is not necessarily the direct short-term goal of innovation policy, it is still promoted through direct or indirect routes. This chapter analyses the theoretical links between innovation policy and economic growth, and synthesises the findings from the empirical research into the effects of innovation policy aimed to overcome the market and system failures. This allows for identifying both the background for research and the related knowledge gaps existing in the current literature.

1.2.1. Innovation Policy in Economic Growth Theories

This section expands on the role of innovation policy as discussed in the major theories of economic growth in order to connect innovation policy and economic growth on the theoretical level. Here the three approaches, i.e. the neoclassical Solow-Swann model, the endogenous theory of economic growth and the evolutionary theory of economic growth will be discussed.

The neoclassical Solow-Swan model distinguishes three engines of growth: capital, work and technological change. It suggests that innovation policy is implied in the model, even if it is not modelled separately and forms a part of the exogenous technological change factor.

The basic model follows the Cobb-Douglass production function. Consider:

$$Y = F(K, L) = K^{\alpha} L^{1-\alpha} \quad (1.1.)$$

Here, Y is the total output of an economy, K represents capital and L stands for labour. α is a constant, when $0 < \alpha < 1$. The level of the technological advancement

(A) can be introduced in three separate ways as: the *Harrod neutral function*, where A stands for increase in labour productivity, the *Solow neutral function*, where A stands for increase in capital productivity, or the *Hicks neutral function*, where A stands for total factor productivity.

Despite different ways to introduce technology (and hence innovation policy) into the Solow-Swan model, this variable is not directly observable and can only be calculated as the Solow residual. The impact of technology can only be measured, when growth which occurs due to the change in capital and labour is subtracted from the total observed growth (Jones, 1998); yet, even then it is not clear how much of the residual can be attributed to technology, since the stated factor productivity represents all the mechanisms of increase in productivity (Solow, 1956).

The Solow-Swan model cannot explain the shifts in the production function due to the exogeneity of technology. It postulates that such shifts are significant and depend on technological development and innovation activities. If innovation policy is successful in raising the level of technology, then it will obviously lead to higher economic growth. Due to diminishing returns, the only way to drive growth will be through technical changes, which might be encouraged by innovation policy. Without them, an economy would reach the state, where it would grow only extensively, which would not improve the welfare of its citizens, and the country would not be able to catch-up with the more advanced countries.

Additionally, human capital, as an important determinant of the economy's absorptive capacity, may be introduced into the Solow-Swan model (Mankiw, Romer & Weil, 1992). In such a case, the technology is also interpreted as an exogenous variable, human capital serving as an additional explanatory factor. Without the introduction of the endogenising technology, Mankiw et al. (1992) used human capital to enhance the predictive capabilities of the neoclassical Solow-Swan model. The empirical analysis carried out in this thesis showed that the value of constant α is about 1/3, and the value of constant β is also about 1/3. Yet, the model offered by Mankiw et al. (1992) has its shortcomings. It demonstrates the possible channel for the innovation policy to achieve some effect, i.e. the human capital, which may be influenced by innovation policy. But even by adding the human capital factor, more elaborate growth models are preferable (Bernanke & Gürkaynak, 2002). This is particularly the case that the impact of innovation policy on the economic growth is to be explained and understood in greater detail.

Even though the neoclassical theory of economic growth has provided a number of insights, it has its limitations. While it might be argued that the increase in factor productivity (i.e. technological advances in addition to other factors) could explain intensive economic growth, this is not done by the model itself and therefore remains a black-box. Since this variable is exogenous, it does not explain much about why intensive growth occurs both in the developing and the developed economies. The neoclassical growth theory suggests that technology and innovation activities are important, but it is incapable of explaining how it functions.

Hence, the models may be reconciled with the demand for innovation policy, but they do not provide a more elaborate framework, in which the theoretical linkage between innovation policy and growth might be developed. Therefore, despite the obvious links between the innovation activities and growth stressed in the neoclassical theory of economic growth, this approach is insufficient to be employed in the analysis of the effects of innovation policy

As a response to the shortcomings of the neoclassical growth theory, Romer (1986) proposes that it is possible to endogenise the technological advancement. The above described models seem to have paid a disproportionately high amount of attention to the economics of objects but left aside the economics of ideas (Romer, 1992). Yet, it is the ideas that enable the progress of technology and they need to be explored. First of all, ideas differ from traditional products because they partly resemble public goods. This resonates with Arrow's (1962) argument that due to knowledge being (at least partly) a public good, government intervention is needed. However, ideas do not entirely represent full public good, as people may be excluded from using them. Most importantly, ideas do not imply a diminishing marginal product. On the contrary, while the initial construction of an idea creates costs, its copying is virtually costless, the only cost coming from a material object, in which an idea is embodied (Romer, 1992). Thus, if ideas are considered as economic goods, the restrictive assumption of a diminishing marginal product of capital should be eliminated. Therefore, the technological process can be modelled as a production process. This also implies that it is possible to model the effects of innovation policy more precisely than within the frame of the neoclassical growth theory.

The basic model proposed by Romer reminds of the neoclassical Solow-Swan model with Cobb-Douglas production function (Jones, 1998). Consider:

$$Y = K^{\alpha} (AL_Y)^{1-\alpha} \quad (1.2.)$$

Here, Y is the total output, K represents capital, L_Y points to labour that is involved in production, and α is a constant between 0 and 1. It is important to note that there is a major difference from the Solow-Swan model. In the case of Romer's framework, labour is divided into two different segments. Only a part of it, L_Y, produces output directly. Meanwhile, L_A is involved in the creation of ideas, so that L_Y and L_A together make the total labour.

The theory implies that the rate of the technological advancement may vary. First and foremost, the share of labour working with idea-creation may change, resulting in the altering amount of created ideas. This can be related to innovation policy which targets at the increase of the number or quality of the researchers. Secondly, not all the ideas have equal effects. Sometimes the newly created ideas make it easier to develop knowledge across several fields. However, it is also possible that the rate of invention may slow down over time, because it becomes more difficult to generate new ideas (Jones, 1998). Thus, the rate of the technological process (i.e. the speed of idea generation) should not be constant.

Romer's model has opened the way to constructing more elaborate models, specifically including R&D and concerning its impact on growth. One of such models was proposed by Aghion & Howitt (1992). They explicitly insist that innovation drives the long-term economic growth. According to Aghion (2012), this may be the process innovations, product innovations, or organisational innovations resulting from the R&D activities, skill development, etc.

Finally, the innovation activities help to replace the older technology, which leads to higher firm turnover. It reflects the Schumpeterian concept of *creative destruction*. Indeed, innovations follow a random walk and there is no strictly defined way in which they emerge. The technology itself can be excludable, meaning that the innovators may earn benefits through licensing or other means. Such creation of innovation monopoly also requires government intervention in ensuring the protection of the intellectual property rights. Otherwise, entrepreneurs will be less inclined to carry out any innovation activities. Therefore, Aghion & Howitt (1992) imply that, in order to achieve a socially optimal intensity of the innovation activities, the government should provide a solution to overcome market failure.

On the other hand, models may combine the insights offered by the exogenous and endogenous approaches, resulting in the semi-endogenous R&D-based models. The latter proposes the model, where R&D is endogenous, but the very growth depends on the exogenous factors. The criticism lies in the fact that the R&D-based growth models rely on the scale effect, which means that doubling of the resources given to R&D would double the growth rate of output per capita. Yet, the empirical data does not support such an assumption (Jones, 1995). For instance, the increase in the number of the researchers does not lead to an equally proportional increase in output per capita.

It is worth noting here that technology does not take an exogenous role but comes from the activities of the profit-maximising agents. The difference from other R&D-based growth models is that, in Jones's case, the output of the R&D activities is not determined by a clear production function and thus cannot be fully endogenised. Despite the fact that Jones (1995) does not see how the R&D-based growth models account for real world observations, elsewhere he explicitly states that taking social returns to R&D into account, it is clear that the level of private investment in R&D is suboptimal. The optimal level of private R&D investment would be about four times larger than the one found in the discussed study (Jones and Williams, 1998). This presupposes the need for innovation policy that would boost R&D spending in the private sector.

The difference between vertical and horizontal innovations[8] should also be taken into consideration: it may be used for understanding how these different perspectives may lead to economic growth and be stimulated by public R&D spending. However, the findings confirm that both positive and negative impact on growth is possible due to investment displacement that indicates the potential government failure. The relative importance of a vertical or horizontal engine might be more significant for growth (Segerstrom, 2000). Therefore, R&D policy should target at the 'correct' engine, as otherwise the effect on growth can be negative. Thus, it is vital for the policymakers to identify correctly which type of innovations should be promoted throughout innovation policy.

The R&D-based growth models have significantly contributed to the comprehension of the role of the innovation activities in the process of economic

[8] In this context, vertical innovation activities are understood as the development of higher quality intermediate outputs. Horizontal innovation activities are understood as the development of different intermediate outputs (Segerstrom, 2000).

growth and the channels through which innovation policy can affect growth. Such developments allowed for constructing the models that are closer to reality than the previous attempts to model economic growth. The greatest advantage of the endogenous theory of economic growth over the Solow-Swan model is that it successfully overcomes the obstacle of zero intensive-growth.

Despite its improvements, the endogenous growth theory has some drawbacks. Firstly, it deals with a number of rather abstract concepts which are difficult to measure (e.g. the elasticity of research productivity). Secondly, the endogenous growth models cannot successfully account for the empirically observed conditional convergence, as there is no inherent reason in the model for such a phenomenon to emerge. Therefore, their predictive power seems better than that of the neoclassical theory of growth only in some way, which leads to a division between the proponents of the neoclassical theory of economic growth and those in favour of the endogenous growth theory. To say more, the endogenous growth theorists do not consider such a very important factor as institutions (Foss, 1998), which, actually, further limits the applicability of the endogenous growth theories.

All in all, the endogenous growth models provide a better and more sophisticated framework for the analysis of the impact of innovation policy on economic growth than the neoclassical theory of economic growth. It suggests that the market failure problems should be corrected by government intervention which might lead to the needed adjustments. Therefore, innovation policy turns to be vital in order to protect the intellectual property rights, subsidise the R&D activities, improve the incentives of the private sector to invest in R&D and ensure a sufficient labour force in research. Nonetheless, the endogenous growth theory neither explains the effects of the system failure, nor discusses the rationale for other types of innovation policies than those that aim to solve the market failure[9].

These issues given above are addressed by the evolutionary theory of economic growth. The neoclassical and endogenous growth theories represent traditional (or orthodox) economics, since they mainly rely on similar assumptions. However, there are theories, such as the evolutionary theory of economic growth that differ from the

[9] The only exception could be human capital and learning which stes outside the boundaries of market failure and are more related to system failure's case of inefficient institutions which provide sufficient training.

already discussed approaches in very substantive ways.

It should be maintained that the evolutionary approach is not dominant in economics (Beinhocker, 2006), even though its ideas are time-tested and stem from Veblen and Schumpeter (Čiegis, 2006). The emergence of evolutionary economics coincided with an overall tendency to adopt evolutionary thinking across social sciences in the 1960s and 1970s. One of the differences between orthodox and evolutionary economics lies in their interpretation of the economic agents and their behaviour. If orthodox economics suggests that the economic agents try to maximise profit, evolutionary economics, in its turn, suggests that their basic goal (even if not consciously perceived) is survival. As the agents differ between themselves, the chances of their survival are not equal across the entire population. The competition for survival can be described according to replicator dynamics, where the probability for the survival of the specific agents depends on their fitness value[10] and on the average fitness value of the population, in which they find themselves. Therefore, contrary to the representative agents assumed in orthodox economics, here the differences between the agents perform the most important role. Due to the competition between the agents, the average fitness value of a population will grow (Lane, 1992). This will be achieved through the changes within the population. Concerning the fitness function which defines the fitness value for each agent, the following three scenarios are possible:

- *Fitness function does not change*. Only those agents that have the highest fitness value do survive, while others with lower fitness die out (Mulder, De Groot & Hofkes, 2001).
- *Fitness function evolves endogenously*. Not only the survival chances of the agents, but the fitness function itself may undergo alteration due to the changes in the composition of the population (Mulder et al. 2001).
- *Fitness function is changed exogenously*. It occurs when there are changes in the environment (e.g. the changes in the institutional arrangements that exist in a country) (Beinhocker, 2006).

The dynamics within the population of the economic agents redefine the fitness function and hence average fitness of the entire population: higher fitness leads to

[10] Fitness is a measurement of the relative performance of an agent in a given environment (Nelson, Dosi & Helfat, 2018).

higher economic growth rate. Therefore, the question is how this fitness might be enhanced.

The main driving force of the economic growth remains the development of technology and knowledge, similarly to the claims of the neoclassical and endogenous growth theories. Here, knowledge and innovations are considered as both quantitative and qualitative changes in physical and social technologies, which include new organisational routines and activities (Saviotti, 2003). Thus, evolutionary economics is mostly concerned with the issues of transformation of knowledge into wealth and variation of the growth rate. The scholars agree that technological change and innovation are among the most important phenomena covered by evolutionary economics (Witt, 2008).

The relationship between growth and innovation is bi-directional, as both have impact on one another (Metcalfe & Foster, 2010). In this respect, the evolutionary approach to economic growth distances itself from the neoclassical growth theory still further. The new technologies can be acquired in two different ways – through innovation and through imitation (Verspagen, 2001). Therefore, while some agents are apt to innovate and devote their time to the production of new technologies and routines, thus enhancing their fitness level and chances for survival, others simply imitate the successful routines to enhance their fitness.

Since in evolutionary economics the agents differ and strive to survive, for them, the environment plays a considerable role. Therefore, evolutionary economics opens a way for more factors to be included into the analysis of the economic growth. For instance, in orthodox economics, variables such as institutions may have a short-term impact on growth, while in the long-run economies will still tend to converge to their market equilibria. In evolutionary economics, the environmental changes may exogenously modify the fitness function that defines the fitness values of the economic agents. Due to the absence of the market equilibrium solution any alteration may potentially have long-term effects on the whole population, as the growth curve changes in a significant and permanent way.

The fitness function depends on external factors as well, which show that innovation policy is in demand. It may correct the systemic issues by encouraging the specific behaviour of the agents, if applied correctly. In fact, government intervention can create or modify the institutions, aid in competence building (i.e. changing the fitness values of the specific agents), network design, etc. In other words, in the evolutionary approach, innovation policy may help correct the system failures and thus increase agent fitness and ensure the survival of the most promising agents.

This perspective has important implications with regard to innovation policy. Firstly, evolutionary economics explains the economic growth by enhancing the agents' fitness, which is determined by knowledge creation and/or its adoption (i.e. innovation and imitation). Therefore, the innovation systems operate as an important determinant of the economic growth. Due to their evolutionary nature, innovation systems depend most crucially on the institutions and learning (Edquist & Hommen, 1999). Thus, it reflects the system failure aspect of the innovation activities and presupposes the need for the specific innovation policy instruments.

One of the implications of the evolutionary theory of the economic growth is that the economic processes are unpredictable. Since the economic growth does not converge to a specific point, only future trends may be guessed and with large margins of error. Another implication is that while the evolutionary economics does not explicitly predict convergence, it accepts that such a process is possible in some periods of time and solely within the groups of the specific countries (Verspagen, 2001). Thus, only from this perspective the empirically observed conditional convergence can be explained.

Although the evolutionary theory of the economic growth has its advantages over the approach of orthodox economics, it certainly has its own drawbacks. Firstly, it is a pure ex-post theory as opposed to the ex-ante one. Hence, it cannot be used for a successful prediction of the future events (Verspagen, 2001), only for broad tendencies. Secondly, since no market equilibrium is expected, it becomes more difficult to analyse the aspect of growth by using the theoretical framework of evolutionary economics than the orthodox approaches.

However, the evolutionary theory of the economic growth has an advantage over the neoclassical and endogenous theories of growth in that it acknowledges the issues related to system failure: institutional, network and related problems that may have detrimental effects on the economic growth. Therefore, it implies the demand for such innovation policy that would aim at correcting the system failures. While the particular recipes may be unclear due to the inherent unpredictability of the economic processes, the ex-post analysis may tell which innovation policy directions should be preferred to alternatives.

1.2.2. Innovation Policy and Economic Growth: Evidence on Market Failure Policies

This section deals with market failure and the traditional innovation policy instruments that aim to correct the failure. They include public subsidies, intellectual property rights protection and taxation incentives. The evidence of the effects of these instruments on the economic growth will be further discussed.

Public subsidies of the R&D activities and economic growth. Most studies find a positive impact of R&D subsidies on the total factor productivity. The panel data analysis embracing 65 countries in between 1965-2005 has found out that a 10% increase in public R&D spending leads to a 1.6% increase in TFP (Bravo-Ortega & Garcia Marin, 2011). Similar findings have been presented in other research as well, whether cross-country, for individual countries or industries (Brecard, Fougeyrollas, Le Mouel, Lemiale & Zagame, 2006; Mamuneas & Ishaq Nadiri, 1996; Minford & Meenagh, 2018; Niininen, 2000; Piekkola, 2007). Brecard et al. (2006) propose a two-stage impact of R&D subsidies on growth. The first stage consists of the effect of R&D subsidies, while the second one involves the effects of the developed innovations through increase in productivity and competitiveness. Capron & de la Potterie (1997) propose that not only the publicly subsidised R&D has a positive effect on the economic growth, but this effect does not differ from the effect produced by private R&D spending.

Another important aspect is that although public R&D spending may have a positive effect on labour productivity growth, nonetheless, private R&D spending can be more important (Coccia, 2012). However, public investment in R&D increases private investment in R&D, which means that R&D subsidies may also increase labour productivity though indirectly. For example, the analysis of 16 OECD countries indicated that the impact of public R&D depends on the amount of business investment in R&D (Guellec & de la Potterie, 2003). Yet, the elasticity of research carried out in universities and in the government sector indicates that public research is also important for the economy.

The industrial sector is another factor, on which the effect of R&D spending also depends. The size of the effect varies with regard to the R&D intensity of industry. In the industries with low R&D intensity, public and private investments are more likely to be substitutes. In high R&D intensive industries, the two types of investment are complementary (Mamuneas & Ishaq Nadiri, 1996). Thus, the relationship between

R&D spending and growth is complex, as the effects are dependent on the economic environment, where spending is made.

Despite the evidence of the positive effect of R&D subsidies, such link is not universally accepted. For instance, by using the data from 30 developing countries in 2000-2006, Samimi & Alerasoul (2009) have found that R&D spending and the related variables have no significant impact on the economic growth. While such findings contradict the ones from the previously discussed works, it should be noted that: a) this sample concerns the developing countries exclusively, thus limiting the generalisability of the findings; b) the time period spans only seven years, which might be too short for the identification of the impact of R&D.

With respect to the differences between the effects of public and private spending on R&D, the results are sometimes also contradicting the dominant narrative. For example, the analysis of the Central and Eastern European countries in 1998-2008 showed that the private R&D accounts for 0.05% increase in the economic growth, while the public investment in R&D has no significant effect (Silaghi et al., 2014). Again, a rather small non-random sample means that the results cannot be generalised, and the CEE context may lead to such results.

A rather new line of research on the relationship between R&D subsidies and the economic growth is the analysis of the effects of this type of policy during the period of an economic crisis. There is evidence that in Germany, during the crisis of 2008-2009 the deficit spending included the subsidising R&D activities of the firms (especially SMEs). The findings are that R&D subsidies helped to slow down the economic decline and prevent the GDP from shrinking further by 0.5% in 2009. R&D spending was more effective than private consumption stimulation, and there are backward multipliers that demonstrate the leverage effect (Brautzsch, Guenther, Loose, Ludwing & Nulsch. 2015). To sum up, further research on the effects of public investment in R&D during the periods of recession is in demand. However, the mentioned study supports the argument that R&D subsidies impact the economic output positively even during economic decline.

Although there are some contradictory studies when samples cover only the developing countries, the overall public investment in R&D has a positive impact on the TFP and, consequently, on the economic growth. Thus, an active policy of the government spending on R&D may be justified. It shows that this type of innovation policy is indeed desired for correcting the market failures and promoting growth.

Intellectual property rights and economic growth. Another activity of the market-failure oriented innovation policy is the protection of the intellectual property rights (IPR). It should lead to increased growth by moving a country's economy toward its optimal growth trajectory (the Solow-Swan model), or by increased returns (the endogenous growth theory). Yet, in the empirical assessment of the impact of IPR on the economic growth, there is little research, not least because of the difficulties in measuring the IPR. The researchers mostly use either patent indexes or dummy variables (Falvey, Foster & Greenaway, 2006). This makes it more difficult to: a) measure the impact of the non-patent aspects of the IPR systems; b) assess the strength of the IPR protection systems. Furthermore, the impact of the IPR might be indirect (e.g. through trade, FDI, etc.), which makes the reconstruction of the channels even more difficult (Taylor, 1994). Though, nonetheless, evidence exists.

One of the few non-index variables used to assess the impact of the IPR is the number of patents given to a specific country. This indicator shows whether the government enforces patent protection and how much likely the organisations are to look for protection of their intellectual property. Nevertheless, there are issues with this measurement. Firstly, the organisations may expect small or no profit from their inventions. Secondly, the sheer number of patents also accounts for the quality of the innovation activities rather than the IPR enforcement.

The historical data show that the countries without patent systems were not always less innovative than those which ensured the IPR protection. During the 19^{th} century, the countries, which did not have patent systems, did not generate fewer innovations than the countries with patent enforcement. Such a situation might be explained by the fact that the high costs of patenting and low quality of protection enforcement meant that it was seldom profitable to be applied for patents in the 19^{th} century (Moser, 2003). However, the research on the later period, when the protection quality increased and costs became lower, discovered that the IPR had a positive impact on the output of an economy. This is related to Nordhaus' (1969) analysis, which provides an ambiguous view of the IPR impact on the economic growth. It has been found out that the IPR lead to higher output but at the cost of productivity, as it is negatively correlated with the IPR.

It is interesting to stress that the findings on the effects of the modern IPR systems differ, suggesting that it is still a contested field of analysis; the results also differ. There are studies that (in most cases) find an unconditional positive impact

(Gould & Gruben, 1996; Hammami, 2013; Hasan & Tucci, 2010), the ones that find a conditional positive impact (Falvey et al., 2006; Ginarte & Park, 1997; Thomspon & Rushing, 1999) and those that find a negative impact of the IPR on the economic growth (Adams, 2009).

The researchers related with the first category claim that the IPR positively affect the economic growth. This is the case with the study covering open economies in 1960-1988, where the use of the model of instrumental variables led to the conclusion that the IPR impacts the economic growth positively (Gould & Gruben, 1996). The analysis of the panel data of 58 countries in the years between1980-2003 found out that the number of patents impacts growth, and increase in patents are related to the increase in the rate of economic growth (Hasan & Tucci, 2010). Such findings are supported by other research (cf. Hammami, 2013). While the number of patents, which is sometimes accentuated in the studies, might not be necessarily the best proxy for the IPR — at least some form of protection is necessary for the number of patents to grow.

However, the non-linearity of IPR effects can be very complex (Hudson & Minea, 2013), and the studies in the second category find that IPR has positive impact on economic growth only if a certain country has already reached a certain level of development (Thomspon & Rushing, 1999; Falvey et al., 2006). A possible explanation for this finding is that IPR has positive effect on capital accumulation which leads to economic growth (Ginarte & Park, 1997). Since capital accumulation varies depending on country’s development, there might be a difference between developing and developed countries with respect to the impact of IPR on economic growth.

The moderating effect of the level of development has been identified in research. A study of 55 countries in 1971-1990 with three models (with growth rate of real GDP per capita, TFP, and patent protection as dependent variables) showed that TFP affects real GDP per capita growth. In high income countries, patent protection positively impacts TFP (Thompson & Rushing, 1999). This indicates that IPR might influence growth indirectly through TFP, also if enabled by an already sufficient GDP level. A more detailed classification of countries (instead of dichotomous low-income and a high-income groups) shows that the effect of IPR on growth may disappear in medium-income but not in low-income countries, without becoming detrimental (Falvey et al., 2006). Still, some studies find that IPR can have negative impact on economic growth (Adams, 2009). Here, the strength of IPR measured using Ginarte-Park index of laws was found to correlate negatively with economic growth. However, the sample also included developing countries. Thus, the results may have limited generalizability.

Overall, the studies on the impact of IPR on economic growth strongly suggest that the effect of IPR depends on the level of development of a country. In high income countries the effect is positive, which might be due to increased innovation activities. In developing countries the effect varies. There are indications that in low income countries there might be positive effect (probably due to increased FDI), but other studies seem to contradict such findings. Medium income countries seem not to enjoy the positive effects of IPR. Having all of this in mind, it appears that the enforcement of IPR should take into account the specific context of a country because the positive effect of IPR is not universal.

R&D tax incentives and growth. The third type of innovation policy for correcting market failure is R&D tax incentives. In this case, impact on growth might be indirect. Tax incentives first lead to higher R&D spending, then to increased TFP and growth. The first link has been consistently supported by empirical evidence (cf. Bayoumi, Coe & Helpman, 1999; Griffith, 2000; Griffith, Redding & Van Reenen, 2001; Howitt, 1999; Rao, 2016). However, research on the relationship between taxation and innovation-driven economic growth is lacking (Aghion, 2012). Nonetheless, several studies were aimed at analysing the relationship between R&D tax incentives and growth. Their main drawback is that they are largely US-centric. Such focus can be explained by highly limited data availability on this policy instrument. It is also more difficult to compare across countries, since the mechanisms (how, who, for what some can an economic agent apply) are often very specific.

One of the important questions that can help to decide on the relevance of R&D tax incentives is whether losses in tax revenue increase R&D spending to at least a similar level. There is evidence finds that losses in tax revenue created by lower taxes, increase R&D spending with ratio of one to two, which also led to an increase of GDP growth by 7.5% in 1980-1991 in the US (Hall, 1993). The study suffers from being restricted to a single country and a relatively short period, thus, its generalizability can be questioned. However both links (i.e. tax incentives – higher R&D spending and higher R&D spending – higher economic growth) have been tested and identified. Another important finding of the study is that it takes time (several years) for firms to adjust to R&D-related tax changes. Thus, the effect might be unnoticeable in the short-run; even if it is positive in the long-run.

Comparing income losses with increased R&D expenditure also raises questions regarding the efficiency of R&D tax incentives relative to R&D subsidies. There is evidence that the former instrument may be less efficient, but incentives can complement direct public investment in R&D by encouraging private sector to invest in this kind of activities (Mamuneas & Ishaq Nadiri, 1996). It may also depend on whom the funding reaches, with subsidies being more suitable for young firms or firms that are not yet carrying out innovation activities (Busom, Corchuelo, & Martínez-Ros, 2017) and different industrial sectors reacting differently to R&D tax subsidies (Castellacci & Lie, 2015).

R&D tax incentives are meant to reduce the costs of R&D activities. Evidence show that a 10% reduction of R&D costs leads to an increase in private R&D spending by 11% in the short-term, with the effect becoming stronger in the long-term (Rao, 2015). Nonetheless, results cannot be generalised, since the data covers only US-based firms in 1981-1991, which might not reflect firm behaviour today and in different contexts.

Even though the research on the effects of R&D tax incentives on economic growth is limited, existing evidence suggest that tax incentives lead to higher private R&D spending. The effectiveness of taxation policies might be disputed, but existing studies indicate that there is positive influence. However, this conclusion should be taken with a grain of salt, as studies on taxation usually cover individual countries or even specific industries within those countries and their generalizability is unclear. The effects of R&D tax incentives depends on a variety of factors (Busom, Corchuelo, & Martínez-Ros, 2017; Castellacci & Lie, 2015).

Although the majority of studies identify a positive link between innovation policy and economic growth, there are some contradictions in the findings. All three discussed types of innovation policies correcting market failure seem to have positive effect on economic growth in advanced economies. However, there are contradictions in findings related to developing economies. Such exceptions suggest that there might be differences in the effects of innovation policy, depending on sample-specific contexts, such as the income level in a country.

1.2.3. Innovation Policy and Economic Growth: Evidence on System Failure Policies

Research within the evolutionary-structuralist framework has failed to generate a high amount of research on specific innovation policies at system failures and their link with economic growth. This may be due to the fact initial innovation indicators were developed for the analysis of linear innovation model (Godin, 2014a). Despite the emergence of the broad concept of innovation policy, the data and indicators mostly still depend on the narrow view, partly due to operationalization of innovation systems policy being challenging, as Rodríguez-Pose & Crescenzi (2008) note. Furthermore, performance indicators should also account for the maturity of technology system, and relying on composite indicators instead of individual simple ones could be preferable (Carlsson, Jacobsson, Holmen & Rickne, 2002). Despite the lack of studies on the economic effects of policies correcting innovation systems failure, a more substantial body of research was created in the field of innovation system studies. Thus, this section concentrates on what research on innovation systems tell about economic growth, and the implications of findings for innovation policy.

So far, the systemic view is included in the main policy documents defining innovation activities (OECD, 2015; OECD & Eurostat, 2018), but lacks a more holistic approach in practice. Even the EU shows a predominantly outdated understanding of innovation policy. Only 22% of respondent states heavily use demand-side policies, and only 37% of responding countries have set up special institutions covering innovation policy at the highest government levels, according to a survey of the EU Member States (Edquist, 2014)

The methods of the analysis within the innovation systems approach somewhat differ from the ones used in market failure research. Statistical analysis is occasionally used, but the field also relies on case studies. One of the most prominent innovation system analyses is Freeman's (1995) study of national innovation systems in their historical contexts, covering a selection of OECD, ex-USSR, Asian, and Latin American countries. Freeman (1995) demonstrates that national innovation systems and institutional variance that formed in those countries determined the difference in economic growth rate. Other case studies also proved to be illustrative, such as showing how institutional and social environment helped to shape innovation systems South Korea and Taiwan and helped to create prospects of higher rate of economic growth (Parto, Carli & Arora, 2005).

Despite the more ‘fuzzy’ concepts used in innovation systems research, there have been quantitative studies, which connect the innovation systems and economic performance. A good example of such statistics-based study is provided in Fagerberg & Srholec (2008). The study covered 115 different countries in 1992-2004. Four composite variables were constructed to represent innovation system, governance, political system, and openness. Factor analysis showed that innovation system composite variable is significantly related to economic growth. The higher the value of innovation system composite indicator, the higher is the rate of economic growth. The results are robust, consistently positive, and statistically significant in different models employed in the study. Thus, the findings indicate that well developed innovation systems are important drivers of economic growth.

Another, more specific, innovation policy instrument that might be linked with the evolutionary-structuralist framework and system-view of innovation activities is the promotion and encouraging of cooperation between industry and universities. There is evidence that in West German lands in 1992-2002, the business-research cooperation was important for growth as it provided the path for commercialisation of universities’ research and the transformation of knowledge into innovations. It was also demonstrated that the effect of industrial grants provided to researchers is positive and statistically significant, meaning that relations of universities and industry are important in fostering economic growth (Müller, 2005). This effect might be explained by knowledge transmission which makes it easier for entrepreneurs to transform knowledge into profitable innovations. Therefore, there is a need for policymakers to further strengthen the ties between research organisations and industry. This might be the case, when supporting start-ups that might lack the means to acquire needed research (Müller, 2005).

Innovation systems approach also differs on the level of systems. On the one hand, national systems can be studied (cf. Fagerberg & Srholec, 2008). On the other hand, innovation systems can be regional. Research shows that innovation activities are often regionally bounded, therefore, innovation policy results can be region-dependent, and depend not only on R&D investment but also on socio-economic factors, such as education, human resources, employment, or demography. The core regions strongly benefit, while peripheral regions benefit less (Rodríguez-Pose & Crescenzi, 2008). Based on the findings, Rodríguez-Pose & Crescenzi (2008) claim that linear innovation policy (e.g. investment in R&D), especially in the periphery, should be supported by complementary policies involving education and other areas that might help with innovation activities. This reflects to the systemic understanding of innovation activities, correlates with the evolutionary-structuralist view of innovation policy, and echoes Edquist (2014) by stressing the need for a broader innovation policy. The regional approach provides an additional perspective to the innovation systems approach. It helps to a) account for the effect of neighbouring regions; b) include specific measures which allow assessing inter-regional connections; enhancing the capabilities of the analysis.

Interconnectedness plays an important role in innovation systems view. This can come from geographic interconnectedness as discussed above or from institutions. Indeed, innovation activities interact with institutions to an important extent. Simulation and empirical research suggests appropriate changes in political institutions[11] and governance quality have positive impact on innovation activities (d'Agostino & Scarlato, 2014). Combinations of geographic and institutional factors are also important for innovation system performance. Socio-institutional environment might lower transforming knowledge into innovations and regional environment might hinder the capabilities to absorb technology, as evidenced by research on Italy (d'Agostino & Scarlato's, 2012). Yet, public policy should attempt to create cooperation networks, and all in all, the provision of public services should be a top priority for the government.

The worse performance of specific regions, such as Southern Italy (d'Agostino & Scarlato's, 2012) might come from lower absorptive capacity of economic agents. Evidence shows that both technological and capacity competitiveness (related to absorptive capacity but broader) affect economic growth (Fagerberg, Shrolec & Knell, 2007), and regions may simply be unable to absorb available funding efficiently (Oughton, Landabaso & Morgan, 2002; Muscio, Reid & Rivera Leon, 2015). Thus, innovation policy should take such factors into account.

The overview of studies analysing relationship between innovation systems and economic growth tells that such relationship exists, and authors are more unified than in the case of scholars studying effects of linear innovation policy on economic

[11] Political institutions are understood as in Weingast (1995), institutions that govern political decision-making, which can be understood as rules governing how policy choices are made.

growth. However, analysis in the evolutionary-structuralist framework suffers from difficulties of operationalization as the review of studies has shown. Such studies often use non-overlapping sets of variables, which further advances the argument for the need of more studies in this field, since results are promising but there is a lack of a unified methodological approach to the problem. In addition to that, there is a lack of empirical research on the relationship between innovation policy in the broad sense and the functioning of innovation systems which must also be carried out, as its results could be promising and could be used to improve national and regional innovation systems, as well as promote economic growth.

The analysis of the theoretical links between innovation policy and economic growth and the empirical evidence on the effect of policy instruments show several things. First, the neoclassical theory of economic growth considers technological change to be an exogenous factor, presupposing the potential need for innovation policy, but not modelling it more explicitly. Therefore, while it stresses the need for innovation activities, it does not help to understand through what channels innovation policy could improve economic growth.

Second, the endogenous growth theory and its specific applications show that innovation policy can improve economic growth through correcting market failures. Empirical studies of R&D subsidies, IPR enforcement, and R&D tax incentives also find that mostly, such interventions positively affect growth, even if contextual factors (e.g. income level) can affect policy effectiveness.

Third, the evolutionary growth theory suggests that environmental factors are important; showing how innovation policy aimed to correct system failures may work. Although the scope of empirical studies are more limited than in the case of the endogenous growth theory, there is evidence that innovation systems affect economic growth. These findings suggest that in innovation policy should also focus on system failure as well.

Finally, the innovation systems approach and evolutionary growth theory suggest that institutions play an important role in defining the environment of innovation creation. However, the growth theories and the majority of the studies do not specifically address the government failure in innovation policy and its likely effects. This tendency leaves a gap hindering our understanding of how innovation policy affects economic growth.

1.3. Electoral Institutions and the Link Between Innovation Policy and Economic Growth

All three major theories of economic growth – neoclassical (Mankiw et al. 1992; Solow, 1956), endogenous (Aghion & Howitt, 1992; Jones, 1995; Romer, 1990), and evolutionary (Santangelo, 2003) – agree on the importance of technological change and innovation activities. These different theories also define ways in which innovation policy might be used by governments to foster growth. In the case of the neoclassical theory of economic growth, long-run economic growth may diminish due to marginal returns of capital per worker. However, by stimulating technological shifts, innovation policy might lead an economy to a higher steady-state of economic growth. The endogenous theory of economic growth shows how innovation policy may help solve market failures and promote growth through subsidies, tax incentives, IPR protection, and education. Finally, evolutionary theory of economic growth shows how innovation policy can help solve or at least alleviate system failures, thus fostering growth. As discussed evidence shows, innovation policy may increase economic growth by correcting both market and system failures. However, there is a lack of theorizing on how government failures can be incorporated into models relating innovation policy and economic growth.

Although government failure poses significant problems for the knowledge economy, the models of economic growth do not primarily cover this issue. The evolutionary theory of economic growth comes closer, due to the emphasis on institutional environment. However, it does not explicitly focus on the issue of government failure. This chapter looks at the government failure in the context of innovation policy and its implications for policy outcomes (i.e. economic growth). Based on the agency problem that public policy faces, it is argued that government failure can also exist in innovation policy and influence its effectiveness.

Government acting as the agent and society as the principal, there is a risk that government's actions will not be fully aligned with the preferences of the society. If the society's and government's preferences were perfectly aligned, then the policy would be optimal to ensure market equilibrium. However, since the preferences differ, the policy is sub-optimal and does not lead to a socially beneficial outcome. The discussion in this chapter addresses government failure in innovation policy in this context.

1.3.1. Government Failure in Innovation Policy

Despite the lack of studies of government failure in the context of innovation activities, it has been suggested that policymakers should consider the possibility of government failure, when choosing policy (Martin & Scott, 2000). However, even when acknowledging the risk, government agents may use policy tools for their own benefit rather than for the social good. That is, better understanding of risks by the agents does not necessarily mean, that it will be beneficial for them to abandon a particular policy. For example, due to the agency problem, understanding how institutions work may even help governments to maximise own gains, such as increasing the likelihood of re-election, instead of maximising socially important output.

The understanding of government failure in the context of innovation policy depends on the conception of government agent. Indeed, one of the challenges that studies of innovation policy are facing is the idealisation of policymaking in the process of transferring innovation policy recommendations from theory to practice. There is a tension between the views of government as a failure-fixer and an entrepreneurial agent. While the latter view was criticised (Flanagan & Uyarra, 2016), researchers often consider entrepreneurial government as an idealised goal, which should be sought. In this context, entrepreneurial state would seek better results from innovation activities and policy recommendations should work because the government agent is not self-interested. However, the concept of proactive, (non-personal) results-oriented policy entrepreneur is too strongly emphasised (Flanagan & Uyarra, 2016), and a ‘representative government agent’ with innovation-driven mindset is hardly a reality. Such representative agent is not likely to be realistic and loses its agency, thus, effectively brushing the agency problem in government failure as irrelevant. This can lead to a wrongful conviction that policy recommendations will necessarily lead to positive outcomes, if implemented by governments. This is not the case, as governments may implement recommendations first of all based on their own preferences.

A counter argument can be made that despite government failure, the entrepreneurial state is beneficial. In this view, it is natural that some of the government policies fail, but the benefits outweigh the negatives. Although this view seems logical, it focuses on a different level of failure – specific policies instead of government behaviour in general. The government failure framed in the terms of the agency problem does not say that a particular project might fail – it might, or it might not, depending on the case. Rather, agents have incentives to act in a way that does not allow reaching the optimal intensity of innovation activities. If a policy is beneficial to government agents, it will be implemented in a way that benefits the society. If it is not beneficial to government agents, society does not benefit as much. Therefore, framing government failure in terms of failed specific policies is irrelevant to this study. Here, the incentives for general government behaviour are more important.

Since institutions play a role in the behaviour of government agents, they should be restructured so that they would force the government to act more strategically (Aghion, 2012) and benefit the society. The institutions could define the boundaries for the intensity of government intervention with a deregulated free market and the state planning being the two extremes. On the one hand, the discussed theories of economic growth imply that government intervention is necessary to bring the level of innovation activities nearer to the socially optimal point. The potential for market failure in innovation activities suggests that a completely deregulated free market approach would lead to socially non-optimal intensity of innovation activities. On the other hand, the complete state planning policy would give tools to government agents to maximise personal gains ignoring individual agents' preferences, which would also be harmful to the economy and the society. Thus, the question of the scope of government agents' involvement is important. This dissertation looks at the democratic countries, therefore, the highly intense state planning is not that relevant. Nonetheless, institutions can define how strong the government involvement in the economy can be and the potential for failure as well.

Given the nature of the agency problem at the government level, the government failure may manifest in three ways, in the context of innovation policy:

- The government might have insufficient information and use wrong policies which might be not only sub-optimal, but also harm the economy. Decisions made under imperfect information can be detrimental. In the case of neoclassical growth theory, such effect would be related to the exogenous variable representing technical change and could not be more properly explained. In the case of the endogenous growth theory, it could mean that the government does not know what the preferable level of R&D investment is and the socially preferable level of R&D spending would not be achieved.

In the case of evolutionary theory of economic growth, the lack of information could lead to failures in various situations that would include harmful education policy, the lack of development of important networks between agents carrying out innovation activities, and many others. Even if the harm is not done to the innovation system per se, the misallocation of resources already suggests that policy is neither effective nor efficient, since these resources could have been spent elsewhere.

- The government might not have appropriate means to implement effective and efficient innovation policy. Then, it would also be unable to achieve the socially preferred level of innovation activities in a country. Again, in the case of neoclassical theory of economic growth, this effect would remain unseen and behind the explanatory capabilities of the model, affecting the Solow residual without a clearly explained mechanism. In the case of endogenous theory of economic growth, it could be possible to assess what kind of policy was lacking, and this could also be reflected in the evolutionary-structuralist framework and the evolutionary theory of economic growth, where standard policy instruments are supplemented with a more holistic policy approach (cf. Edquist, 2014). However, in both endogenous and evolutionary theories of economic growth the intensity of government involvement via innovation policy could be assessed, suggesting a potential inclusion of government failure.
- Finally, individual agents in the government and the government (as a collective agent) might not try to reach the goal of socially optimal level of innovation activities. Instead, based on the interest groups and electorates on which they depend, the government might rather aim at increasing its chances of survival in office (cf. Bueno de Mesquita, Smith, Siverson & Morrow, 2003) using the existing institutional setting than providing the optimal level of innovation policy with socially efficiency. The role of institutions in determining policy success can be illustrated by an example of cluster policies, there being evidence that institutions and path-dependence play an important role in policy success (Uyarra and Ramlogan, 2016). As in the previous cases, the neoclassical theory of economic growth falls short of including this into analysis. Endogenous theory of economic growth could include the outcomes of such non-optimal innovation policy, but it is the

evolutionary theory of economic growth is the most suitable in explaining this type of government failure due to its broader scope and innovation systems view, as well as the stress that it puts on the importance of institutional environment which might cause government failures.

Although there are few empirical studies on government failure in innovation policy, evidence shows that, for example, R&D expenditure is susceptible to government failure. The analysis of policy transparency has shown that innovation activities is among the areas with the highest rate of bid rigging and an average corruption level (Wensink, de Vet et al. 2013). This shows that the agency problem is an active issue in innovation policy, with government agents being self-oriented rather than innovation entrepreneurs without personal interests.

Thus, although discussion of government failure and its effects on innovation policy is limited, literature acknowledges the existence of the agency problem. Even if it is not explicitly stressed in the economic growth theories, the taxonomy of government failure discussed in Chapter 1.1 implies that government actions can have detrimental effects on growth in the context of innovation policy as well.

1.3.2. Political Institutions in Neoclassical and Evolutionary Economics

Having identified the role that institutions may play in developing government failure, it is worth defining how political institutions can be framed in the studies of innovation policy. This seems natural, as politicians and governments make decisions about public policy, including related to innovation activities. In this context the potential for government failure emerges. Generally, the inclusion of the political institutions in economic research may be approached from two perspectives – neoclassical and evolutionary. Such division reflects the two theoretical approaches discussed in the previous chapters.

Generally, the analysis of economic effects of political institutions and constitutions started since about 1950s with Buchanan’s work, partly leading to the emergence of a separate subfield of economics – constitutional economics, which looks at rules of choosing political leaders and decision making processes (Congleton, 2018). Since then, the field of constitutional economics has significantly broadened. Particular attention has been paid to the economic effects of electoral systems. Mostly, the constitutional economics (cf. Knutsen, 2011; Person & Tabelinni, 2005) tend to focus more on the neoclassical economic approach. At the same time, an alternative approach could be suggested based on the evolutionary approach to economics. In this case, while still adhering to the concept of government maximizing its chances to remain in office, the effects could be treated differently. The difference on where the focus is put, is also the difference between affecting specific economic agents (increasing/ decreasing their fitness value in the neoclassical approach) and affecting the fitness landscape[12] in which they function (affecting the fitness functions in the evolutionary approach) (based on ideas discussed in Beinhocker (2006)).

Policy interventions are significantly more important in the latter case, since then they can affect the fitness of firms or fitness landscape in ways more profound than subsidies or similar policies could. Affecting specific agents and increasing their evolutionary fitness is likely to have more incremental effects on economic development than modifying the whole evolutionary fitness functions by making them friendlier to agents carrying out innovation activities. Although all economic policy areas are important for firms and the fitness landscape, innovation policy is especially important, since (successful) innovation activities greatly affect firms' chances of survival (Cefis & Marsili, 2005). Innovation activities allow modifying both an individual firm's fitness and the fitness landscape, where firms function.

Irrespective of the differences between neoclassical and evolutionary economics, political institutions can be accounted for in both cases. The interpretation may differ, but the expected effects can be seen as comparable. Indeed, even in the neoclassical economics, using the linear model of innovation, the policies can be aimed at targeting specific entities (e.g. funding for specific research institutions) or all economic agents (e.g. by tax incentives). Therefore, the distinction between neoclassical and evolutionary economics here comes more from interpretation of behaviour rather than from the consequences of government actions.

Despite some theorising, on the links between political institutions and innovation policy, discussed above, empirical studies on the effects of political institutions on innovation policy and economics is rare. There are two main types of research: a) concentrating on the effects of specific institutions; b) assessing the

[12] A fitness landscape is "the distribution of fitness values to all possible [fitness] configurations" (Nelson, Dosi & Helfat, 2018, p. 76).

general effects of the political system on economic development and its links with innovation. The first line of research focuses on specific institutions and for a large part, it is similar to standard research in the field of constitutional economics. However, research connected specifically to innovation policy is much scarcer.

The analysis of existing literature allowed identifying only a single study (Kim, 2011) which concentrated solely on assessing effects of specific political institutions on public R&D investment. The main theoretical basis for the study is the distinction between private and public goods. Depending on the nature of R&D spending (i.e. public or private good), the effects might differ. Kim (2011) finds that:

- countries with parliamentary constitutions tend to spend less on R&D than countries with presidential systems
- countries with majoritarian electoral systems tend to spend more on R&D than countries with proportional electoral rules;
- the effects of a particular institution may depend on other institutions existing in the same country (i.e. their interaction may strengthen or weaken the effects)
- bicameral democratic systems spend more on R&D than unicameral ones

However, theorising behind the findings is not conclusive and more reminiscent of ad hoc rationalisation of why they are as they are. A more elaborate theoretical argument is constructed by Batinti and Congleton (2018) in the study of voters' preferences and government's spending on healthcare R&D. They hypothesise that healthcare is a public good, important across the whole electorate. Therefore, it should be expected that governments will prefer to focus their R&D expenditure on this objective. This should result in the advancement of medical technology, related to healthcare expenditure, as the empirical evidence suggests (Batinti and Congleton, 2018).

Another possible approach is to frame the discussion of the political economics of innovation and their effects within the varieties of capitalism framework. Here, partisan politics could play a role especially on the relationship between innovation activities and social inequality (Huo, 2015). This potential research area is important, since it "open[s] up the prospect for a theory about the *partisan politics of science policy*" (Huo 2015, p. 231-232), suggesting that political factors play an important role in the implementation of innovation policy and its effects. Still, further empirical investigation into the actual effects is lacking, and only a suggestion of possible research area is provided there.

The second line of research tries to generalize the political systems of different countries on a single scale. On the one hand, such approach has the benefit of allowing easy cross-country comparison, also making it easier to identify the effects of political setting from the methodological point of view. On the other hand, such approach suffers from two issues. First, it is more difficult to provide satisfying theoretical reasoning why artificially simplified institutional indices should demonstrate certain effects, since institutions are often not comparable directly (as in better vs. worse). Second, the aggregation of the different elements of constitutional systems into a single artificial concept may hide the effects of specific institutions, thus either not allowing identifying which institutions are important, or completely hiding some of the effects of if different institutions provide opposite results. Therefore, such research should be taken with a grain of salt, even if it provides important insights.

An example of the paper in this line of research, which also includes innovation activities, is by Fagerberg & Srholec (2008), where several factors are used to create an mixture, which represents political system of a country. It provides a compelling view of the effect that these specific factors have on economic development. However, the study also touches upon the individual relationships of attributes of political systems to a composite indicator of innovation system, but finds no strong links between them. On the other hand, this approach does not take specific institutions into account. Thus, while an index of the level of democracy or legislative system's restrictiveness might provide equal score to two countries, their constitutional organisation (and potentially effects) may differ, and due to such variation, research may provide skewed results if we focus on specific institutions.

In the light of the discussed theoretical approaches, it could be argued that Kim (2011) is closer to the neoclassical view of economics, due to the way that innovation system is approached – linear relationships are expected and the focus of research is on R&D policy, making study close to the linear model of innovation. Meanwhile, Fagerberg & Srholec (2008) are closer to the evolutionary view due to their focus on the effects of institutional (not only in the political sense) and other factors related to the evolutionary view (but not explicitly showing). In the latter case, the effects are also studied with a broader view – education, infrastructure, patents, and publications are included as elements of innovation system, and the relationship between political and innovation systems is studied with regards to their interactions at the system level. Similar to this approach is Fagerberg (2015), who discusses institutions as the 'rules of the game', but remains at a meso-level, concentrating on laws lower than constitution. Still, the evolutionary view in such studies may be limited to the selection of important factors rather than in the broader methodological choices. Once the factors related to the system or holistic view of innovation are selected, the empirical strategy is often the same as in the neoclassical framework.

Neither type of available empirical research fully covers the role of political institutions. Existing studies tend to lack theorising on the role of specific institutions and either takes them as a factor without firm theoretical background discussion or presents the general effects of political system without deeper consideration of particular institutions. This leaves a knowledge gap for further investigation, including theory building, especially since results of these studies are encouraging and show the relationship between political institutions and innovation policy. Furthermore, these studies are individual and scattered rather than forming a part of a larger body of literature. Thus, there exists space for additional research.

Political institutions could be classified into those set rules for political decision making (e.g. the defining the relationship between different branches of government) and those that affect political decision making through incentivise agents in acting in certain ways in order to increase their chances of staying in office. The logic of how these types of institutions may affect decision making differs. Further in this dissertation the focus lies on the second type, electoral institutions, because they have a clear link with re-electoral incentives, and therefore, may be of primary consideration for policy choices. These institutions define the rules of how the government is elected, directly affecting the welfare of government agents and, consequently, incentives for their behaviour. Therefore, government agents are likely to utilise policy instruments, including innovation policy, to 'game' the rules imposed by the electoral institutions[13] and so increase their chances of survival in the office. The following Section 1.3.3 discusses how electoral institutions can be expected to affect innovation policy.

[13] Electoral institutions term in this paper refers strictly to the constitutional rules of electing individuals to office, but not to institutions as organizations (e.g. electoral commissions or others). The term is used interchangeably with electoral systems.

1.3.3. Electoral Institutions and Innovation Policy

To explain the role of political institutions in general, and electoral systems in particular, the view of a self-interested government is adopted. Here, the government is understood as a subject (also consisting of government agents), who wishes to keep the position in office. Even though government agents might have specific goals dictated by their personal values, in order to achieve these goals the government must first of all ensure that it can stay in power long enough to adopt and implement envisaged policies. The only way to ensure that policies preferred by the government agent will be implemented is through securing re-election and prolonged stay in office. This means that the primary aim of the government agents is to survive in office, a view adopted by researchers in political science as well (Bueno de Mesquita, Smith, Siverson & Morrow, 2003).

An assumption is made that under normal political conditions (i.e. no state of emergency, sudden existence-threatening crises such as war, etc.) governments should first of all aim at being re-elected and try to keep the office for as long as possible.[14] In order to achieve this, a government must satisfy the needs of its winning coalition (Bueno de Mesquita et al. 2003). Here, it is important to note that winning coalitions are not all similar across democracies. While in some democratic countries the size of the winning coalition might be close to half of the electorate (citizens of the country who have the right to vote), in others a much smaller winning coalition would prove sufficient for keeping control of the government. Accordingly, policies should differ based on the size of the electorate, the size of the winning coalition, and the ratio between these two sizes. The present study focuses particularly on the electorate in democracies (rather than the selectorate in dictatorships), and therefore considers the implications of electoral systems on government agents' incentives to implement innovation policy.

Therefore, while implemented policies would vary depending on who controls the government (e.g. government agents' ideology, personal preferences, etc.); the way in which the policy is implemented should also be aimed at maximising the chances of re-election by favouring the interests of the incumbent's winning coalition

[14] This also applies when the government is formed and appointed by the parliament, since the results of the parliamentary election define which parties form the government.

and ensuring sufficient support during the coming elections. This is a horizontal issue and should hold true for innovation policy among other policy areas. For example, a government may decide which technologies and fields of science should be supported and how the support will be provided specifically. This is likely to be based on increasing re-election chances. Several examples of such policies could be: a) support provided only to the largest enterprises / research institutes; b) investment in agents implementing innovation activities that are established in locations important for the government during the elections; c) providing a broad support to a larger number of agents that implement innovation activities, thus affecting a larger share of the population.

The high importance of elections and their impact on government actions suggest that voting rules are among the most important institutions for policymaking. The electoral rules, through setting the rules of electing a government, define how government agents should aim to improve their re-election chances. Therefore, the electoral institutions (proportional, majoritarian, or mixed rules of electing politicians to office) are especially prone to contributing to institutional government failure. They create an agency problem, where societally beneficial outcome is not the most preferred outcome for a government agent due to re-election goals.

Generally, scientists define two broad types of electoral systems:

- proportional representation, where the district magnitude is large, sometimes equalling the size of the whole country, and the seats in the parliament are distributed proportionally to the votes received
- majoritarian, where district magnitude is small, and individual *candidates* compete to become members of the parliament in a small district, where one candidate is usually selected, thus leading to less proportional results

In the first case, geographical policy dimension is less relevant, as the votes are distributed more equally across the country, and the voters focus on parties or political movements. Therefore a single vote in one region is more equal to a single vote in another region and there are no reasons for government agents to focus on specific geographic areas. Rather, it is important for the government that the policy positively affects as large a group of voters as possible irrespective of their location.

In the second case, the opposite is true. A single vote in one region is not equal to a single vote in another region, and here voters elect particular candidates. Some regions already have favourite candidates / parties and are unlikely to elect a representative of another party. However, other regions are still ‘undecided’ and are more likely to change their preference from one party to another. Therefore, the government agents aiming for re-election should target a smaller number of people in key districts. Such policies would have larger impact on the outcome of the election, and help ruling parties to increase their seats in the parliament. Therefore, under such conditions, any policy, including innovation policy, should target specific locations.

Therefore electoral institutions should be considered in analysing institutional government failure in policymaking. More specifically, depending on the electoral rules, it may be worth for government agents to focus either on policies that target particular geographic locations or on policies that target the general population and therefore affect a larger number of voters who are, however, dispersed. Thus, in such case the rules of election should play an important role in shaping any policy, including innovation policy.

The type of electoral system suggests what type of policies governments should prefer, social transfers or regionally bounded public goods. Therefore, innovation policy must be defined in this respect for further analysis. The categorisation follows Milesi-Ferretti, Perotti & Rostagno (2002), who suggest (and find empirical support for) two hypotheses relevant for the present research. They find that:

- transfer spending is higher under proportional rules
- public goods (regionally bounded) spending is higher under majoritarian rules

This correlates with the assumptions on the importance of geographic location, public goods are considered to be bound geographically (e.g. investment in infrastructure in a specific location is a public good, but bounded geographically). Meanwhile, transfer spending affects the citizens of the country in general. Accordingly, it is expected that policy in democratic countries will be more geographically concentrated in the case of majoritarian electoral systems, and less geographically concentrated in the case of proportional electoral systems. This should allow governments to increase their chances of survival in political office, by affecting the voters whose support is crucial for re-election.

The issue of geography in public spending is closely related to the nature of goods provided (cf. Milesi-Ferretti et al. 2002). Thus, it is important to determine what type of goods is spending on research and innovation activities. It is argued that such expenditure is difficult to define strictly as a public good or transfer spending (Kim, 2011). Depending on a specific policy instrument or its characteristics, it can be any of those or somewhere in between (e.g. tax incentives are closer to transfer spending, whereas support for applied research is more likely to be a geographically bounded public good due to it being more beneficial to particular agents). Therefore, depending on the specific electoral system in a country, spending may be either more transfer-oriented or directed more at regionally bounded public goods.

Evidence suggests that innovation policy is generally closer to providing regionally bounded public goods than to providing social transfer payments due to geographic concentration of innovation activities (Rallet & Torre, 2017). Therefore, innovation policy should be more intense under majoritarian electoral institutions than under proportional ones. This would be in accordance with the findings of Kim (2011) that governments under majoritarian systems spend more on R&D. There are several reasons, why it should be expected that innovation policy more resembles policies that provide regionally bounded public goods rather than social transfers.

First, given the importance of infrastructure, collaboration, high quality human resources, etc. for R&D activities, it should be expected that innovation activities flourish in locations which provide innovation- and business-friendly environment. Indeed, as conclude, innovation activities are geographically concentrated (Feldman & Kogler 2010; Ferru & Rallet, 2016; Rallet & Torre, 2017). Due to such concentration, not only funding specific economic agents, but also providing a broader policy, such as tax incentives, undeniably has a geographic dimension. First and foremost, the agents in locations with intense innovation activities will use these available policy sources. Thus, the benefits and impacts of innovation policy will also most likely be concentrated in those specific regions.

Second, an argument could be made that R&D spending directly affects only a small share of the population. Less than 1% of population are researchers, and even though R&D spending affects more people than only researchers (e.g. the employees of the benefiting firms), the number of voters affected directly in a way that they would relate their well-being to R&D spending, is low. Other policy instruments, such as social transfers (e.g. social benefits to specific groups) are likely to affect a higher number of people, and the effect is likely to be more direct. Therefore, under proportional representation electoral systems, investment in R&D might serve as a means to increase the number of voters, but the payoff is likely to be low. Due to the clustering of R&D activities, such investment might pay off better in countries with majoritarian electoral systems. Thus, governments elected under majoritarian rules should be more in favour of broader innovation policy.

The arguments discussed above suggest why countries depending on majoritarian electoral rules should be expected to spend more through innovation policy. However, it does not necessarily mean that such spending will be highly effective or efficient. Not only the intensity of policy, but also the impact of innovation policy may also be affected by the electoral system. The performance would likely be higher in countries with proportional electoral institutions, because innovation policy under majoritarian electoral rules is more likely to be directed towards improving re-election chances. On the contrary, in countries with proportional electoral rules, innovation policy is more likely to be oriented towards ensuring better economic outcomes. Even if innovation policy may directly affect only a relatively small share of the population, improving economy and available improved or new products and services, or increased access to new technologies may help to attract voters. For governments elected under proportional electoral rules, innovation policy would not be the main tool for maximising their electoral chances. Therefore, they could think of policy impacts rather than primary beneficiaries as affecting their chances of survival. Interestingly, the studies of policy effectiveness in the light of specific political institutions (including electoral systems) are lacking, although it might be very fruitful. Associating policy intensity with electoral systems is important, but it is even more important to understand if this policy is effective and efficient. Current studies do not actively study this issue,[15] and it is an important research gap to be addressed. After all, the intensity of policy in itself does not tell much, if it is good for society or not.

The arguments above could be framed in the context of neoclassical and evolutionary economics. Following the logic discussed above, the more re-election depends on specific geographic locations, the more the government should be interested in supporting specific agents in important locations. If, however, re-election is independent from geographic location, the government should concentrate more on affecting the fitness landscape in general, thus, promoting a more rapid change in

[15] Although many address the effects of electoral systems on macroeconomic outcomes (Milesi-Ferretti et al., 2002; Kim, 2011; Knutsen, 2011; Persson & Tabellini, 2008), there is a lack of actual assessment of when policies are more socially beneficial.

the economy and a more demanding environment, in which they should improve their performance. In this way, more agents would be affected, potentially reaping higher benefits from such policy during the election due to increased economic outcomes in general. This could suggest that proportional electoral systems would lead to more effective and efficient innovation policy due to broader (if not deeper) impact, and shows that geographical aspect is important in both neoclassical and evolutionary approaches.

As already noted in Section 1.3.2, the logic explaining how and why innovation policy should be affected by the constitutional setting is reconcilable with both neoclassical and evolutionary economics. It may be used to study innovation policy from both a linear model and systemic perspectives. Given the importance of the geography of relationships between firms, the evolutionary approach to constitutional economics of innovation policy is more likely to produce more interesting results, if it is used to inform the hypotheses and use of variables in empirical studies.

To conclude this section, innovation policy is a special case for the study within the scope of constitutional economics. Both the theory and what scarce empirical evidence exists support the idea that constitutional setting of a country affects the innovation systems and innovation policy. Electoral systems should play an especially important role due to it being among the determinants of the incentives for government agents. Therefore, the theory developed further in this dissertation focuses on the electoral systems. It is suggested that due to the nature of innovation policy as a geographically-bounded public good, it is more likely to be more intense in countries with majoritarian electoral institutions. However, it is also more likely to be less effective than in countries with proportional electoral institutions. Previous research has not provided in-depth theoretical reasoning on the role of electoral systems in innovation policy and, therefore, this constitutes a gap in knowledge, which is addressed by this dissertation.

After reviewing relevant empirical research, several conclusions can be drawn. First, empirical research on the impact of innovation policy on economic growth mostly belongs to the neoclassical framework. Even if it discusses innovation systems and other aspects of innovation policy that might be related to evolutionary-structuralist view, the policies they analyse are more related to correcting market failure. Second, there is a rather wide variety of indicators used to measure innovation policy. While it is more unified in the case of neoclassical framework, there are differences even there. In the evolutionary-structuralist framework the issue of choosing indicators becomes even more problematic, as system view implies a lot of factors that affect innovation activities and their outcomes. Third, hypothesized channels of how various policies impact growth also vary, which shows the need for more research on how government support for innovation activities is transformed into economic benefits for the society.

Although the theoretical link between innovation policy and economic growth seems clear, findings of empirical research carried out both within the neoclassical and the evolutionary-structuralist frameworks is not so unified. Results vary, some of them demonstrating a positive impact of innovation policy economic growth, some of them showing no relationship, some of them even drawing attention to negative influence of innovation policy on economic growth. This shows that there is no strict scientific consensus neither on the specific effects of innovation policy on economic growth, nor on what variables should be used to measure innovation policy, which is especially the case in the evolutionary-structuralist framework. This demonstrates that there is a need to further develop methods and models which could be used to measure the impact of innovation policy on economic growth. Adding specific context of electoral systems, which might impact how innovation policy is implemented in a country and how important it is for growth, expands the current research from the perspectives of constitutional economics, growth economics, and innovation economics. Strongly related is the economic geography of innovation, which needs new perspectives added to the quite robust findings that the field has already provided (Ferru & Rallet, 2016). This dissertation contributes to these areas and helps fill the existing knowledge gaps.

After analysing the scientific discourse on the innovation policy, its relation to economic growth, and the role of political institutions, gaps in the existing research were identified. The next part of this thesis deals with developing a theoretical framework for addressing these gaps and discusses the specific theoretical and methodological issues related to developing tools for the analysis of the impact of innovation policy on economic growth in the context of electoral systems. Based on the broad conception of innovation policy discussed in Chapter 1.1 and its role in theories of economic growth as discussed in the Chapter 1.2, the potential role of electoral systems outlined in Chapter 1.3, and existing empirical research, a framework connecting innovation policy with economic growth in the context of electoral institutions is developed.

2. METHODOLOGY FOR ASSESSING THE IMPACT OF INNOVATION POLICY ON ECONOMIC GROWTH IN THE CONTEXT OF ELECTORAL INSTITUTIONS

2.1. Modelling the Relationship between Innovation Policy and Economic Growth in the Context of Electoral Institutions

The analysis of literature explaining the impact of innovation policy on economic growth indicates directions for constructing theoretical framework for the current assignment. This chapter develops a conceptual model, based on the literature analysis carried out in Part 1. It provides a coherent theoretical explanation of the impact of innovation policy on economic growth in the context of electoral institutions. Consequently, the sections of the chapter concentrate on:

- the particular determinants of economic growth through total factor productivity, identifying the channels for innovation policy to affect growth
- the innovation channels and innovation activities that are important for the analysis of economic growth
- defining the role of electoral institutions in the context of the modelled links between innovation policy and economic growth

By the end of the chapter, a coherent theoretical model is presented, turning the discussion towards methodologies that could be used to assess the proposed model.

2.1.1. The Determinants of Total Factor Productivity

Two basic alternatives exist for developing a growth model – the Cobb-Douglas production function and the constant elasticity of substitution (CES) production function[16]. Whether the basic technology-driven growth function with the Cobb-Douglas or the CES production functions are taken, both are mainly driven by capital, labour, and the total factor productivity[17]. As discussed in the first part of the dissertation, the total factor productivity is strongly influenced by the technological change. While technology is an exogenous factor in the neoclassical growth theory,

[16] However, it should also be noted that Cobb-Douglas is just a particular case of CES, when elasticity equals 1.

[17] Even though, some authors include human capital (e.g. Mankiw, Romer and Weil, 1992) or natural resources (e.g. Chamber & Guo, 2007) as additional inputs.

the endogenous growth theory attempts to transform it into an endogenous one, such as with models mainly driven by knowledge production.

In general, growth literature mostly agrees on the basic drivers of economic growth. Labour, capital, and total factor productivity are considered to be such, both in the neoclassical and the endogenous growth theories. Indeed, this distinction goes back to Solow-Swan model (Solow, 1956). Labour and capital are often considered to follow Cobb-Douglas production function and contribute to growth with diminishing returns. Even if, as noted above, CES production function may provide a different interpretation of the role capital and labour, it still uses both of these factors as determinants of economic output and its change.

In the neoclassical growth theory, the Solow residual is a combination of all factors that are not covered directly by labour and capital, but still affect economic growth. Therefore, the third traditional driver of growth – total factor productivity – includes not necessarily only technology, but also any other factors that are not captured by labour or capital. To conclude, these three factors – capital, labour, and total factor productivity – cover the main determinants of growth.

*Capital accumulation***.** Capital has been considered as one of the main determinants of growth since even before the development of Solow-Swan model (e.g. Harrod-Domar model). Capital investment provides equipment and infrastructure for workers to use in production. Both the amount and the quality of the equipment and infrastructure directly affect output per worker, and the more output a worker produces, the faster the economy grows. However, capital provides output with decreasing marginal returns. Therefore, with each increase in capital stock per worker, its output will increase but with diminishing returns, meaning that capital accumulation has a certain boundary for the effect on growth. Therefore, the evidence and theory suggest that capital affects economic growth, but with diminishing marginal returns, capital cannot be the only driver of long-term economic growth without interacting with other factors.[18]

Labour. In addition to capital, output production requires labour. The labour force must both have demanded skills, and be of sufficient quantity. Here, the relationship

[18] The exception could be Von Neumann machines or artificial intelligence driven capital, which could be made to function with little to no interference by workers. This could lead to a capital-driven growth with little or no decrease in marginal returns with an additional unit of acquired capital.

between labour and capital is very important. The growth of capital has diminishing returns if the labour force does not grow at a constant rate. However, if growth in capital is accompanied by increase in the size of the labour force, the extensive economic growth could continue without necessarily increasing intensive growth (i.e. economic output per capita). This implies that: a) if the growth of capital is too rapid, it will eventually reduce returns to additional capital to zero; b) if the growth of labour is too rapid, it will have diminishing returns due to the lack of infrastructure and equipment needed for the most efficient production given the technology level. Therefore, the relationship of capital and labour with economic growth is interrelated.

Furthermore, labour may be divided into two categories, which have differing effects on growth (as it is done in some of the models, e.g. Romer, 1990):

- capital intensive labour, which produces capital-based outputs (the amount of capital is important)
- knowledge intensive labour, which produces knowledge-based outputs (the amount of capital is important only in so far as it is related to knowledge production, e.g. research equipment or infrastructure)

In the first case, innovation policy does not get explicitly involved. In the second case, the training of knowledge intensive labour force could be encouraged through innovation policy (under its broad definition).

Neither labour, nor capital can by themselves drive intensive growth without limits. Due to the diminishing returns and limits of labour growth, even unbounded increase in capital would eventually reach zero level of growth in output per worker. Therefore, the main driver of long-run growth is not increase in capital or labour, but rather factors, which increase labour and capital productivity. In the case of the Solow-Swan model, such element was defined by the Solow residual. That is, all variables affecting growth which are not capital and labour.

Total Factor Productivity. Total factor productivity (TFP) has been studied since at least 1950s and the development of the Solow-Swan economic growth model. Its studies remained relevant due to both increasing amount of available data (including at the micro-level) and new developments in methodological approaches (Van Beveren, 2012). What makes TFP different from other variables in the production function is that it is not directly observable. In the neoclassical growth theory it is defined as the Solow residual, everything that is neither labour nor capital. Such elusiveness makes it difficult to pinpoint the exact meaning and composition of TFP, which makes it an important object of study. There is evidence that the share of TFP in economic output/growth partly depends on how advanced a country is. In low-income countries this share is smaller than in medium- and high-income countries. However, the contribution of TFP to growth is very clear in all cases (Bulman, Eden & Nguyen, 2014). The difference might be due to low-income countries needing to catch-up in terms of the amount of capital per worker.

Despite the fact that TFP has been studied for over half a century, it is still not entirely clear what it is made of, and different explanations have been provided. They include a variety of variables ranging from patents to entrepreneurial systems and institutional structures (cf. Acs, Estrin, Mickiewicz & Szerb, 2014). Due to such broadness, the TFP can incorporate not only factors that come from the linear model of innovation or the narrow conception of innovation policy (e.g. R&D subsidies), but also factors, which are important in the innovation systems approach (e.g. technology transfer).

Often TFP is associated or even equated with knowledge or the level of technological development, which is considered to be responsible for the lion's share of the Solow's residual. However, research shows that although a significant part of TFP indeed is related to knowledge/technology, the remainder is driven by other factors which cannot be easily tied to innovation activities (Isaksson, 2007). Based on this review, Table 4 provides an overview of components that can be considered as contributing to TFP, as identified in the literature and relates them to innovation policy, which helps to identify factors with potential relevance for the model used in this dissertation.

Table 4. Determinants of total factor productivity

Factor	**Potential proxies**	**Relation to innovation policy's link with economic growth**
Knowledge creation	R&D investment International patent applications Published articles	Yes, through directly contributing to innovation output
Technology transfer	Foreign direct investment International trade	Yes, through enabling knowledge spillovers
Technology adoption and absorption	Human capital Skills mismatch Standards	Yes, through enabling economic agents to use available knowledge
Health	Rates of disease Rates of disabilities	No direct relationship (though it may encourage more focus on

	Life expectancy	innovation in health area)
Infrastructure	Investment in research infrastructure Investment in physical infrastructure Efficiency of use of infrastructure	Investment in research infrastructure is important for possible innovation activities
Structural change / resource reallocation	Geographic determinants Strength of institutions Composition of industry	Possibly as exogenous factors
Financial system	Real interest rates and other indicators of financial development	No direct relationship
Integration (trade)	Openness Trade orientation Exports	Yes, could be related to technology transfer (see above)
Institutions	Political regime Institutional quality	A potential driver for the intensity and effectiveness/ efficiency of innovation policy
Geography	Type of terrain Resource abundance	No direct relationship
Competition	State-owned vs private enterprises Privatisation	A possible external factor that encourages innovation activities
Social dimension	Income equality Age structure	No direct relationship
Environment	Depletion of resources Degradation of environment Environmental regulation	No direct relationship

Source: partly based on Isaksson (2007)

The large variety of drivers of TFP shows that economic growth is a very complex phenomenon and research should focus on the impact of specific factors rather than aim to provide an all-encompassing explanation of growth. It also shows that quite a few variables are directly related to innovation activities, especially those that Isaksson (2007) attributes to knowledge creation, technology transfer, and technology adoption and absorption. These are the three channels through which innovation activities affect total factor productivity economic growth.

The study further concentrates on these three channels in order to link innovation policy to economic growth. Their importance is made clear in existing studies (Borensztein, 1998; Bravo-Ortega & Garcia Marin, 2011; Isaksson, 2007; Minford & Meenagh, 2018; Runiewicz-Wardyn, 2013). Other factors are not included due to several reasons:

- the need to focus the study and not to overcrowd the models with variables of little relevance for the research question addressed in the dissertation
- the empirical focus of the study is democratic countries with market economy, therefore, providing relatively homogenous group of countries in many respects, limiting variance in some other factors, such as the ratio between state and private enterprises

Nonetheless, there are challenges with the use of knowledge creation, technology transfer, and knowledge absorption for this research. First, just as is the case with total factor productivity, they are difficult to be observed directly and, therefore, must be measured through proxies. Second, they themselves are affected by different variables, both related to policy and not. Therefore, a specification on how these channels are understood and assessed in the current framework must be provided when developing the model. Nonetheless, such classification captures different aspects of innovation systems, and can serve as a good tool for further analysis.

2.1.2 Innovation Policy and Innovation Activities

The previous section identified the main factors affecting growth, both related to innovation activities and not. Since the latter are to be modelled more extensively, it is essential to discuss them in greater detail, identifying how they work and what is their relationship to each other. Accordingly, this section explores channels relating innovation policy with economic growth. As shown in Section 2.1.1 above, a variety of factors affect TFP. Based on Table 4, specific innovation activities-related determinants and their dependence on innovation policy are discussed below.

Knowledge creation*.* Knowledge creation affects growth because it increases the amount of knowledge, which allows creating marketable innovations and helps to increase the productivity of capital investment and labour. Knowledge creation is also one of the main targets of public innovation policy, whether a government subsidizes innovation activities, leverages private investment, introduces tax incentives, or takes other similar actions. Such policy decisions affect knowledge creation and, consequently, TFP (cf. Soete & ter Weel, 1999). The examples of indicators listed in Table 4, shows that in that classification two types of indicators are listed under one category of knowledge creation – input and output. R&D expenditure would fall under knowledge creation inputs, while publications and patents are outputs of knowledge creation. The (public) expenditure is a direct indicator of policy, while innovation outputs are more related to the results, and incorporate both the effects of public and private knowledge creation, as well as other factors, such as knowledge absorption, or technology transfer.

Therefore, the knowledge creation measurement is separated into three parts:

- government knowledge creation – government's inputs into knowledge creation processes
- private knowledge creation – private sector's inputs into knowledge creation process
- innovation output – the results of innovation activities

Such classification ensures a better reflection of the input-output structure of knowledge creation and allows to measure policy more directly. In addition to innovation policy, private investment in R&D is also an important determinant of innovation output. Therefore, it is also included, by developing a private knowledge creation indicator, comparable to the government knowledge creation indicator.

Technology transfer*.* Technology transfer affects growth by increasing the outputs of innovation activities and firm productivity. In this case, knowledge is not created but acquired from other economic agents. Although this means that innovation activities do not take place initially (although technology transfer may lead to innovation activities at a later time), it increases firms' productivity and the variety of their products.

Technology transfer is strongly affected by governments' decisions to adopt specific intellectual property rights' regimes. Furthermore, specific investment in technology transfer entities, cluster policies, etc. are also implemented by governments (cf. Tödtling and Trippl, 2005). Although not all foreign direct investment (FDI) actively enables technology transfer, encouraging FDI, especially from more technologically advanced countries/ enterprises, can lead to successful adoption of knowledge in the host country by domestic firms (cf. Borzenstein, Gregorio & Lee, 1998), although there is discussion on the specifics of the effects of FDI on technology transfer (cf. Van Pottelsberghe de la Potterie & Lichtenberg, 2001). Finally, industry-academy relationships can also be facilitated by governments (Etzkowitz & Ranga, 2010), and this link plays important role in increasing outputs of innovation activities by applying fundamental knowledge to real-world problems. All this shows that technology transfer can be an outcome of innovation policy. In this context, technology transfer enables more firms to get engaged in frontier research and innovation activities. This increases the productivity of capital and labour, as well as the variety of products and services available to consumers.

Due to these reasons, technology transfer is included in the developed model as another innovation channel. There are two caveats with its use. First, it measures the outcomes of economic processes and economic policy. Therefore, it is not measured directly by policy instruments used to attract FDI or increase trade, but proxied through outcomes. Second, indicators, such as FDI, capture more than just technology transfer. It could, for example, impact growth through attracting more capital or encouraging skill development. To overcome this challenge, two links between technology transfer and economic growth must be included in the model – mediated by innovation output (capturing the technology transfer element leading to increased innovation output) and direct capturing other impact on growth, including through adoption of new technology that does not create new innovation output per se. Third, in this dissertation, the focus of technology transfer is international movement of knowledge, not domestic, which is to be more highly related to government and private knowledge creation, as well as knowledge absorption.

Knowledge absorption*.* Finally, in order to be able to use the created or the transferred knowledge, firms must have sufficient absorptive capacity to be able to use it. Without human skills and adequate infrastructure, even gained knowledge cannot be put to its full use and the benefits are suboptimal. Absorptive capacity is especially important for benefiting from the available knowledge, whether created or acquired. Therefore, the increase of absorption capacities should also be positively related to increase in TFP.

Innovation policy instruments may affect knowledge absorption capacity (cf. Tödtling and Trippl, 2005). It is somewhat less dependent on direct investment of governments in specific activities of enterprises. Even if firms adopt technologies (which they are free to choose, and it is likely that, barring high costs, firms will choose the most advanced available technology), they still need enough and adequately skilled labour to be able to produce output with this new technology (Tether, Mina, Consoli & Gagliardi, 2005; Toner, 2011). Here, a government can pursue two strategies and develop human skills in general:

- by providing more favourable conditions to those seeking more education and training

- by directing available resources to those areas, where there is clear skills mismatch and the supply of specific skills is significantly lower (or is expected to be lower in the future) than their demand

In both cases, government's decisions affect both education/ training and outputs of innovation activities. Certainly, public provision of needed research infrastructure also increases absorptive capacity of countries with access to it.

Given the arguments above, knowledge absorption is included in the developed model as one of the innovation channels. There are two caveats with its use. First, it measures the outcomes of economic and educational processes. Therefore, it is not measured directly by policy instruments used to develop skills, but proxied through outcomes. Second, indicators, such as educational attainment, capture more than just propensity to develop or adopt innovations. Higher skills could mean work with higher value added without innovation. To overcome this challenge, two links between knowledge absorption and economic growth must be included in the model. One link is mediated by the innovation output (capturing capabilities to develop innovations or use available knowledge) and direct link capturing other impact on growth, including through higher value added jobs due to higher skills or other means that do not necessarily go through innovation output.

It is worth stressing the mentioned challenges in connecting knowledge creation, technology transfer, and knowledge absorption lie in the adequate measurement of the concepts. In the case of knowledge creation, it is relatively straightforward. Measures such as R&D investment can be taken to reflect policy. However, in other cases, such as technology transfer, the choice is more difficult. Therefore, the following assumptions must be made:

- knowledge creation can be measured through quantitative measures of investment, such as government expenditure on R&D
- knowledge absorption can be measured through outcomes (which depend on policy, but not only on it), such as population with tertiary education or the number of researchers
- technology transfer can be measured through outcomes (which depend on policy, but also not only on it), such as foreign direct investment flows

Knowledge absorption and technology transfer have the limitation that here the policy inputs cannot be easily measured. Furthermore, contrary to knowledge creation, the expenditures may be made through different policy fields (e.g. trade, education policies, etc.). Therefore, it is more fitting to measure outcomes. Certainly, they do not depend only on policy, but measuring outcomes allows measuring the specific relevant aspects of knowledge absorption and technology transfer, since the results show how they affect innovation output in addition to direct effect on growth; and having a more streamlined way to measure the policy and its outcomes, based on the result indicators.

Finally, these innovation channels are measured together with electoral systems, showing how strongly government incentives (based on institutions) can be linked to these particular measures. This allows identifying the effect of policy. Furthermore, it relates to the more holistic view of innovation policy, which requires not only inclusion of R&D or similar policies (based on the linear model of innovation / market failure), but also institutional effect on policies and their outcomes in other areas, such as education or trade.

The discussion above identified the three channels for the effect of innovation policy, namely, knowledge creation, technology transfer, and knowledge absorption. Ideally, it would be beneficial to disentangle private and public activities in each of them. However, due to the aggregate level of data that is available, the model takes into account the differences in inputs to knowledge creation (e.g. R&D investment). In other cases it is likely that the values of indicators are highly affected by public policy and therefore are considered as such.

Each channel is complex, covering a variety of separate activities or results. In order to make a model more manageable, each channel is further modelled as a composite indicator, which is a standard if not a dominant practice in innovation studies (cf. Eggnik, 2012; Fagerberg & Srholec, 2008). Methodological approach to their construction is provided in the later parts of the dissertation, but the remaining discussion in this chapter already focuses on them as composites.

2.1.3. Modelling the Relationship between Innovation Policy and Electoral Institutions

As discussed in Chapter 1.3, the electoral institutions define how governments act. Since governments are mostly driven by their wish to increase chances of getting re-elected, they make policy decisions to maximize their chances of staying in office. Thus, governments make policy decisions, based on their self-interest. This mostly affects the current/ or the short-term policy. It is so because of the electoral cycle, which typically lasts four years (although it depends on a country). Therefore, we can expect that electoral institutions will directly influence government policy decisions at least insofar as they relate to spending, even if not the other types of policy (e.g. IPR regime which would have long-run effects and affect the behaviour of voter to a smaller extent).

Geographic concentration of knowledge and innovation activities suggests that innovation policy is more closely related to regionally bounded public goods. This makes it more likely, that governments should focus on it more if they are elected through majoritarian electoral systems. It should also be assumed that the relationship between electoral systems and innovation policy can be connected to each of the identified innovation activity areas:

- **Knowledge creation** is affected by the relationship between electoral institutions and public policy in general. That is, spending, taxation, and other decisions influence whether the government will be more likely to pursue policy oriented towards provision of regionally bounded public goods or social transfers, affecting the amount invested in knowledge creation.
- **Technology transfer** may be affected by electoral institutions due to differing predispositions towards distribution of knowledge. It is expected that governments will act differently depending on the specific characteristics of institutions and encourage transfer in some geographic locations but not so much in others. Technology transfer can be bounded geographically by attracting knowledge sources to specific geographic areas. At the same time, more innovative areas are more likely to be attractive for foreign investment.
- **Knowledge absorption** is also likely to be affected by government decisions on innovation policy, for example through modifying education policy. Therefore, electoral institutions may dictate how much the enhancing of absorption capacities will be supported.

All in all, there are good reasons to believe that electoral systems affect innovation policy (see Chapter 1.3 for the main discussion) and, consequently, economic growth, at least in so far as it is driven by innovation activities. Therefore, inclusion of these institutions is necessary to identify the impact of innovation policy on economic growth, as they allow making additional insights in this relationship. The electoral rules might affect each of the paths leading from innovation policy to economic growth.

To be able to draw valid conclusions, it should be noted that the relationship between innovation policy and economic growth goes in both directions. Indeed, as was already made clear, innovation policy helps to promote growth. However, innovation policy may also depend on economic growth, thus creating an endogenous relationship between the variables. Studies on the causal relationship between R&D investment and growth indicate that indeed, the relationship between these two variables goes in one direction in one set of countries, but in the opposite direction in others (Santos & Catalao-Lopes, 2014). That is, while there appears to be a link between R&D and growth, it is not clear in which way the causality runs.

This issue becomes even more complicated. Since, a government is bounded to respond to the fluctuations in macroeconomic indicators, its decisions not only affect macroeconomic outcomes, but macroeconomic outcomes also impact government's decisions. To illustrate this, consider labour policy as an example. If the level of unemployment rises, or if there is a lack of workers with specific skills, it is likely that a government in democratic country would adopt new policies or modify the existing ones, so as to decrease unemployment or increase the pool of workers with required skills. This can come in a variety of forms, including but not limited to subsidies to training programmes or attracting workforce from abroad. Such policies would then increase the chances of the government to be re-elected, as voters would react positively to implemented changes. An example related to innovation activities and economic growth could be a fall in GDP, which could affect public R&D expenditure, because funds would have to be channelled to solving more immediate problems.

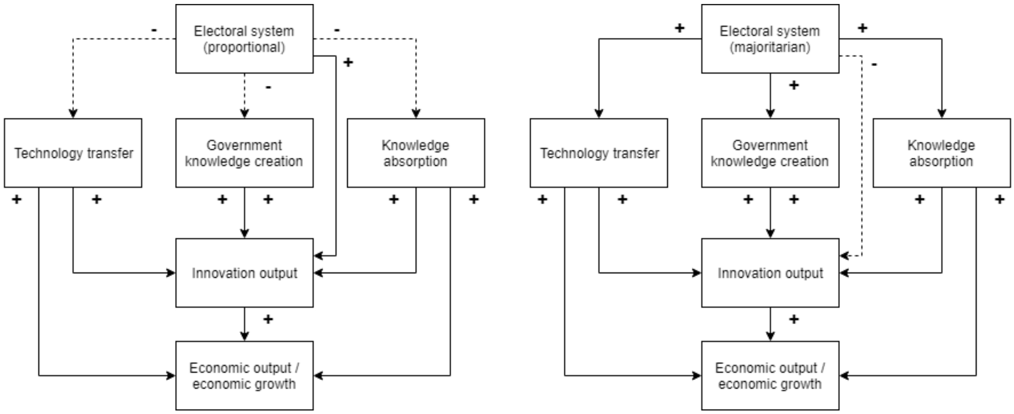
The endogeneity problem affects the analysis of the impact of innovation policy on economic growth. If the rate of growth rate is perceived as high enough, and innovation activities are carried out by firms without additional intervention of government, then it should not be surprising if it does not actively pursue changes in its innovation policy. However, if the prospects of long-run growth are low and performance does not improve significantly, the government might be forced to reconsider its innovation policy. This effectively leads to a conclusion that the direction of relationship between innovation policy and growth can also run in the opposite direction than the one theorized previously and advocated in the study.

Not accounting for the endogeneity of the relationship between innovation policy and economic growth could be a limit of this research. An ideal model should account for both directions of causality evident in implementation of innovation policy (e.g. through Granger causality tests). Thus, growth rate would become not only the dependent, but also the explanatory variable. A similar but opposite transformation would have to be made with innovation policy. However, several reasons may be put forward against inclusion of such relationship:

- Not accounting for endogeneity still identifies relationships between economic growth and innovation policy, even if not the causality. Establishing an empirical link and its sign is already important information that may help improve policy.
- Path models do not allow looped paths (which would be created by the inclusion of the discussed relationship), following tracing rules (Garson, 2014). Therefore, the model cannot be bi-directional due to the inherent methodological limitations.
- Higher growth rate should decrease the amount of innovation activities and vice versa, as governments may consider it sufficient for their purposes. Thus, the relationship between innovation policy and growth would be negative. This means that any positive effect found during the empirical estimation of the model, would likely be downward biased. Although it would make the interpretation of results susceptible to bias, if hypotheses are supported, there would be no other effects on the final assessment of the model. Thus, finding the relationships would already be a significant step towards supporting the model and would help to assess the hypotheses.
- The effect of innovation or economic output indicators on electoral systems is not expected because countries have historically developed systems (only several countries could be considered as exceptions), and therefore, current changes in these variables cannot account for the choice of the electoral system.
- In order to decrease the impact of endogeneity further, the model could also include lag independent variables, so that their values would precede those of the dependent variables. In such way, a temporal relationship would be implied in the model.

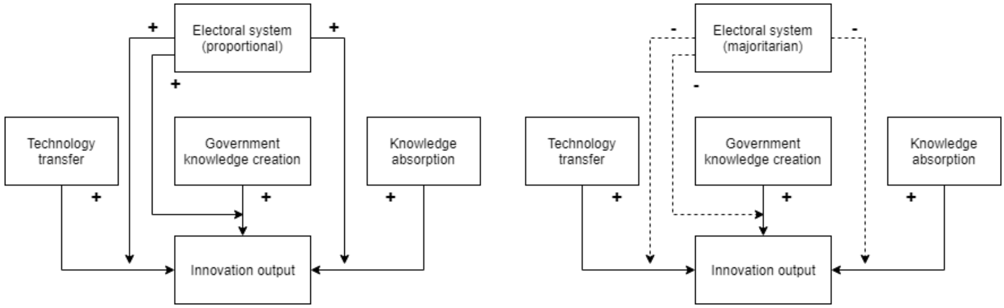
The discussion provided so far outlined the channels of the effect of innovation policy on economic growth in the context of electoral institutions. It includes the three channels of innovation policy's effect on economic growth, the expected effect of electoral institutions, and capital and labour as factors of production. Figure 2 below outlines the structure of the proposed direct effects, while Figure 3 shows the expected effects of electoral systems on the effect of innovation channels.

Figure 2. The expected direct effects between variables.



Note: signs indicate relationship between variables. Dashed lines indicate negative relationship, full lines indicate positive relationship. Signs of effects of electoral systems are relative to the other system.

Figure 3. The expected effects of electoral systems on the links between innovation channels and innovation output.



Note: signs indicate relationship between variables. Dashed lines indicate negative relationship, full lines indicate positive relationship. Signs of effects of electoral systems are relative to the other system.

The proposed conceptual model consists of two types of variables – exogenous and endogenous. Exogenous variables are not affected by other variables included in the models, while endogenous ones are affected by other variables (and may also affect still others). Table 5 describes the type of each variable.

Table 5. Types of variables in the model

Variable	**Variable type**	**Comment**
Electoral institutions	Exogenous	Since the study takes electoral institutions as a contextual factor, no attempts to explain it are made.
Knowledge creation (government)	Endogenous	While the impact of government investment in knowledge creation might be studied by treating it as exogenous, the inclusion of institutional context requires that it is considered an endogenous variable.
Knowledge creation (private)	Exogenous	It is considered that private resources-driven knowledge creation is an exogenous factor in the model. The effect of government-led knowledge creation should be captured by public investment.
Technology transfer	Endogenous	Technology transfer, although also stemming from private resources, is influenced by innovation policy. Therefore, it is included as an endogenous variable.
Knowledge absorption	Endogenous	Knowledge absorption, although also stemming from private resources, is influenced by innovation policy. Therefore, it is included as an endogenous variable.
Innovation output	Endogenous	The variable should be affected by the other discussed innovation channels. Therefore, it is included as an endogenous variable.
Capital	Exogenous	Although capital accumulation is often included in growth models, and it is worth adding it here, no attempts at explaining the factors which affect the rate of capital accumulation, are made, making it an exogenous variable.
Labour	Exogenous	Although labour is often included in growth models, and it is worth adding it here, no attempts at explaining the size of labour force are made. Therefore, it is an exogenous variable in the model.

The following chapter deals specifically with how the relationships between these variables could be estimated empirically. While no econometric analysis is done yet but the main possible methodological are discussed in greater detail, and the choice is made based on their advantages and drawbacks.

2.2. Methodologies for Empirical Assessment the Economic Impact of Innovation Policy

Most of the cross-country research discussed in the first part of the dissertation relies on macroeconometric panel data models. However, more theoretically-grounded approaches and more elaborate models, mostly built on microeconomic foundations, are rarer to find. It is difficult to argue that in order to make informed evidence-based policy decisions, governments must rely on more sophisticated analytic tools. Innovation policy is no exception, and both its theoretical effects and practical implementation have been analysed with the aid of macroeconomic models. However, what might work for the analysis of policy initiatives when forecasting the effects of policy instruments might not necessarily fit theory-oriented macro-level economic research. This section assesses the relevance the main methods that help to empirically estimate the impact of innovation policy on macroeconomic indicators. They are discussed in the context of the theoretical model presented in Chapter 2.1.

Discussion in Chapter 2.2 helps to choose a relevant methodology that would allow incorporating economic theory into empirical model for its validation. Several models, both classical and relatively new, that are used to research economic growth and policy impact on economic growth are discussed. Although, a review of various methodological approaches could be very long and cover various subtypes of the discussed methods, it would defocus this dissertation from its main aim. Therefore, for the purposes of this thesis, only the main classical and emerging approaches to economic modelling will be considered and discussed in the light of the present research.

2.2.1. Assessment of Standard Econometric Approaches

Regression models in growth econometrics

As discussed in the first part of the dissertation, most of the studies analysing innovation activities and the impact of innovation policy on economic growth are based on cross-country panel data or cross-sectional models. This methodology is based on constructing regressions derived from theoretical models, and analysing the impact of different sets of variables on economic growth, and allows studying two basic types of questions concerning economic growth. According to Durlauf, Johnson & Temple (2004), growth regressions can help to assess the differences between economies at an aggregate level, the longevity of such differences, or the factors determining economic growth.

Growth econometrics mainly consists of various regression models, be they time-series, cross-sectional, or panel data. The basic model stemming from neoclassical economic theory (as per Solow (1956) and Mankiw et al. (1992)) can be presented as follows. Consider:

$$\gamma_i = g - \beta logA + \beta logy_{i,0} + \beta \frac{\alpha+\phi}{1-\alpha-\phi} log(n_i + g + \delta) - \beta \frac{\alpha}{1-\alpha-\phi} logs_{K,i} - \beta \frac{\phi}{1-\alpha-\phi} logs_{H,i} + \pi Z_i + \epsilon_i \quad (2.1)$$

In equation 2.1, γ_i stands for growth rate, g – constant rate of technological progress, n_i – population growth rate δ – depreciation rate, A – productivity level, $y_{i,0}$ – output per labour unit, $s_{K,i}$ – saving rate of physical capital, $s_{H,i}$ – saving rate of human capital, Z_i – control variables, ε_i – error term, while α and φ come from three-factor Cobb-Douglas function (Durlauf et al. 2004). This equation serves as the basis for a large body of empirical research on economic growth.

While the basic factors important in growth equations are clear, choosing additional control variables poses a more difficult challenge. Durlauf et al. (2004) list over 140 variables that were found as having statistically significant impact on economic growth. A large number of determinants is also listed in Isaksson (2007), as discussed in Chapter 2.1. This creates a dilemma for a researcher when choosing which variables should be included in a study. The selection of such variables as capital and labour are clear, while the choice of additional variables depends on the purposes of a study in question.

Although most of the empirical research on economic growth is based on cross-sectional or panel data regressions, there are several important criticisms of such approach. These main substantive criticisms are presented in Table 6.

These are legitimate criticisms aimed at regression-based growth econometrics; there are ways to overcome the stated problems. Thus, even though advocating for keeping more advanced econometric models, Durlauf et al. (2004) suggest that supplementing growth research with other methodologies, such as calibrated simulations or more in depth case studies should further extend our knowledge about the determinants of economic growth.

Table 6. Problems related to growth regressions

Problem	Essence	Solution
Endogeneity of regressors	It is difficult to assess whether a particular relationship comes from causality or correlation	Using time-series data and instrumental variables
Non-linearity of effects	Each factor is treated separately ceteris paribus and no interaction between factors is considered, even though theory allows for it	Using interaction terms, i.e. products of variables included in the regression formula
Aggregation	Theory is looking at units smaller than countries, therefore country-level aggregate data are not always suitable	Using non-aggregated data where necessary/ possible
Residual heterogeneity	Exchangeability is not necessarily well founded since variables which are not included might affect various countries differently	Fixed effects and between-country models depending on the situation

Sources: based on Durlauf et al. (2004) and Aghion and Durlauf (2009).

The majority of non-applied research on the impact of innovation policy on economic growth is based on growth regressions. In the case of policies aimed at solving market failure, the regressions are based on either Solow-Swann growth model, neoclassical model extended to include human capital as in Mankiw et al. (1992) or endogenous models. As an example, a model used by Samimi & Alerasoul (2009) might serve, where the impact of public investment in R&D is simply introduced as an addition to standard capital, labour and lagged GDP variables. Consider:

$$ln(GDP_{it}) = \alpha_i + \beta_1 ln(GDP_{it-1}) + \beta_2 ln(L_{it}) + \beta_3 ln(K_{it}) + \beta_4 ln(RD_{it}) + \epsilon_{it} \quad (2.2.)$$

Here, in equation 2.2, the notation is standard as accepted in economic literature, and *RD* stands for public expenditure on R&D. This, most probably, is the simplest possible model of the impact of innovation policy on economic growth, as both innovation policy and control variables are not very sophisticated. However, more variables could easily be added to the model. In addition to including monetary indicators, non-monetary aspects of innovation policy may also be inserted into a regression system, as shown by Thompson (1999).

Although evolutionary economists look at linear regression analysis more sceptically than neoclassical researchers, even the proponents of innovation systems approach do not hesitate to use panel data models to assess the impact of systemic variables. As an example a model by Fagerberg & Shrolec (2008) might serve. Therefore, growth regressions-based approach has an undeniable advantage of being suitable for both neoclassical and innovation systems approaches. In equation 2.3, many variables are used to construct composite indicators representing innovation systems (*IS*), governance (*GOV*), political system (*POL*), openness (*OPEN*) and geography, nature and history (*CONTEXT*):

$$GDP_i = \alpha + \beta_1 IS_i + \beta_2 GOV_i + \beta_3 POL_i + \beta_4 OPEN_i + \beta_5 CONTEXT_i + \epsilon_i \quad (2.3.)$$

The overview of growth regressions shows that despite their certain limits (e.g. imposed linearity, endogeneity, etc.) they were and still remain most widely used to analyse the phenomenon of economic growth. The possibility to estimate the effects of systemic and institutional variables is an important strength of the growth regressions method, especially for research in this thesis, considering the theoretical model outlined in Chapter 2.1. The relevance comes because growth regressions:

- can use cross-country longitudinal data, which is required by the theoretical model
- can use country-level aggregate data, which is the only level relevant and available for the study
- allow incorporating indices, which is important in the context of the theoretical model, because this enables including channels as index variables

No drawbacks specific to the model outlined in this research have been identified.

General equilibrium models

As an alternative to cross-country regressions, general equilibrium models can be constructed where effects can be estimated either econometrically or by using calibration. In this case the analysis is based on constructing virtual economies, where all markets are assumed to be in equilibrium. This section reviews two types of general equilibrium models – dynamic stochastic general equilibrium (DSGE) and computable general equilibrium (CGE) models – and assesses their relevance for the current research.

DSGE models are based on the neoclassical macroeconomic theory and involve stochastic equation systems. The emergence of DSGE models provided economists with a tool to model specific economies. They include the neoclassical assumptions of rational optimizing actors and produce results comparable to real economic processes (Fernandez-Villaverde, 2009). The DSGE approach managed to merge the real business cycle and the new Keynesian paradigm through the New Neoclassical Synthesis. Due to the central role of interest rate in the DSGE models, monetary policy becomes one of the central objects of policy analysis, when using this method.

The dynamic element of DSGE models comes from stressing the dependence of agents' intertemporal choice on the uncertainty of the future outcomes. Therefore, the current state of an economy is considered as depending on agents' expectations. This is mainly driven by the negative relationship between interest rates and current spending (Sbordone, Tambalotti, Rao & Walsh, 2010). This means that when the interest rate rises, current spending decreases and vice versa.

Smets & Wouters (2007) provide the following linearized form of total output of an economy:

$$y_t = \varphi_p(\alpha k_t^s + (1-\alpha)l_t + \epsilon_t^a) \quad (2.4.)$$

As in the Solow-Swann model, output is the function of capital (k_t^s), labour (l_t^s) and total factor productivity (ε_t^a), α stands for share of capital in production and φ is equal to one plus the share of fixed cost in production.

Although DSGE models are used for forecasting, their reliability, especially when forecasting economic growth is not always sufficiently high. VAR models may provide more reliable results than seemingly more sophisticated DSGE models. Therefore, despite micro-foundations they do not offer a panacea in growth modelling.

One of the most important criticisms that sprang initially with the birth of DSGE models, was their inability to account for technological development and the need to include external technological shocks (Fernandez-Villaverde, 2009). This still remains one of the unsolved issues with DSGE models and bears important implications for their relevance for assessing the impact of innovation policy. This might be related to the fact that there is a rather small coverage of innovation policy by DSGE models.

Nonetheless, there are practical examples, where DSGE approach is used to analyse R&D, such as in the case of the European Commission's QUEST model. It might shed light on how DSGE models might serve in assessing economic impact of innovation policy. The basic elements of QUEST include the R&D sector, non-liquidity constrained households, intermediate sector, and high-skill labour. The government's role is to promote innovation activities through tax incentives and subsidies. In this model final goods sector is driven by the intermediates sector and labour (high, medium, and low-skill). Innovation activities play a role through high-skill labour and R&D sector which impacts households through patents. Patents also impact intermediates sector directly. R&D sector itself depends on stock of knowledge and high-skilled labour (Di Comite & Kancs, 2015).

Another DSGE model simulates the United Kingdom to analyse the impact of R&D policy on productivity. It finds positive effect of regulatory and subsidy-based R&D policy on economic growth (Minford, 2015). However, despite being elaborate, the model suffers from the linearity restriction, and does not account for systemic country-level variables, since a single country is analysed. It also shows that DSGE models are large (compared to growth regressions) and may require country-level calibration, limiting their relevance for cross-country studies. This indicates a potential issue for using the DSGE approach in this dissertation.

All in all, DSGE models are not often used to analyse the economic impact of innovation policy instruments. This is due to their size and other limitations (e.g. dependence on exogenous shocks and the lack of theoretical clarity in linearized equations (cf. Schorfheide, 2011)). As discussed in the first part of the dissertation, innovation policy may only be adequately understood if systems view and evolutionary approaches are adopted. DSGE models have difficulties in satisfying these conditions, being firmly based on neoclassical microeconomics. Including system-level determinants may be more challenging. Furthermore, DSGE models are often limited in terms of how many different economies they simulate, making them less relevant for this research, which takes time-invariant country-level factor – electoral systems – as one of its pillars.

Computable general equilibrium (CGE) models are related to DSGE models, but distinct from them in several important ways. The strength of the CGE models lies in their ability to model long-term relationships and, consequently, the long-term impact of stable economic policy. However, being static, they are not so suitable for the analysis of short-term or cyclical changes in the economy. Having in mind that the likely impacts of electoral systems are long-term, this should not rule out CGE as possible methodological choice, even if it restricts its applicability.

CGE models make an explicit assumption that an economy is in equilibrium, as prices balance supply and demand. In such case any economic policy is treated as an external shock to the economy, after which, it goes back to the equilibrium state with modified relations between consumers and producers (Di Comite & Kancs, 2015). The basic agents are firms and households. The prices are adjusted in markets, where equilibrium is achieved. An often used approach to CGE is the reconstruction of industrial production process from primary inputs through intermediate inputs to outputs by creating the so-called production nests. Production functions can then be used with data from social accounting matrices to estimate the impact of different policies on value added and total output.

The first instances of the use of CGE models that include innovation policy (R&D spending to be precise) are found in Diao et al. (1999) and Goulder and Schneider (1999). The CGE model interprets final goods (*Z*) as a sum of value added (*VA*) and intermediate goods (*X*). Labour and capital produce value added. An exemplary CGE model with innovation policy extends the baseline model with knowledge capital (*H*) as a primary factor, which is sector-specific (*i* stands for different sectors of an economy) (Hong, Yang, Hwang & Lee, 2014). Consider the following:

$$Z_i = g(VA_i, X_i) \quad (2.5.)$$

$$VA_i = f(L_i, K_i, H_i) \quad (2.6.)$$

R&D investment is introduced through R&D investment goods (*RDZ*). Consider:

$$RDZ_s = g'(RVA_s, RX_s) \quad (2.7.)$$

$$RVA_s = f'(RL_s, RK_s) \quad (2.8.)$$

In equations 2.7 and 2.8, *R* indicates that specific indicator is related to R&D, while *s* is dichotomous and denotes either private or government investment in R&D related activities.

It is considered that the total value added attributable to research stems from the research-related labour and research-related capital through the Cobb-Douglas production function. Final research goods are then created by value added coming from research and value added coming from intermediate products through the Leontief production function. The final research goods then affect final goods through impacting human capital, which together with capital and labour affects value added through the Cobb-Douglas production function (Hong et al., 2014).

In the applied research, European Commission utilises a CGE model GEM-E3 R&D, which represents 38 economic sectors of all EU Member States and five countries from the rest of the world. Although the model is mostly used for assessment of energy and sustainability policies, it can also account for the impacts of innovation policy, even if mainly in the clean energy sector (Di Comite & Kancs, 2015). In the GEM-E3 R&D model, the value of a production nest is increased by the R&D services. The change in RFP depends directly on the cumulative production and stock of knowledge produced by R&D. ε_1 and ε_2 represent elasticities, while *r* stands for a specific group of countries (Di Comite & Kancs, 2015).

$$\Delta TFP_r = \Delta StockProduction_r^{\epsilon_1} * \Delta KnowledgeRDStock_r^{\epsilon_2} \quad (2.9.)$$

Furthermore, the model accounts for knowledge spillovers stemming from R&D activities. Therefore, it is evident that CGE models have more than theoretical value, and they can be used for practical applications and may provide policymakers with information needed to analyse the economic impacts of government policies.

However, several issues suggest using CGE models for innovation policy analysis with caution. First, it should be noted that the inclusion of innovation policy into CGE models is still a relatively recent advance and the validity of such models should be taken with a grain of salt. Second, as in the case of the DSGE models, they are used within the neoclassical framework, based on neoclassical micro-foundations and are more difficult to reconcile with the innovation systems approach. Therefore, the relevance of CGE for this dissertation is limited.

2.2.2. Emerging Methodologies for Estimating Economic Impact of Innovation Policy

In addition to the discussed popular modelling approaches, often based on the neoclassical foundations, there are emerging methodologies that provide a very different approach to the economic analysis. This section discusses two such methods, each providing a different perspective. Agent based computational models look at the micro-level and model emergent characteristics from agent-level rules. Meanwhile, neural networks approach is non-theoretical and based purely on the data analysis. Both methodologies are assessed for their relevance for the dissertation.

Agent-based models

One of the promising emerging classes of economic models is agent-based models (ABMs). These models differ from both DSGE and CGE models not only in specific ways in which equilibrium is computed, but also in its underlying assumptions. While both DSGE and CGE classes of models belong to neoclassical economics, ABMs are related to heterodox evolutionary economics and assume no such phenomena as equilibria, perfect information, representative agents, or others.

ABMs rely on micro-foundations, but they require neither perfect rationality nor representative agents. In fact, one of the points of criticism towards the methodology of neoclassical macroeconomic models is the complexity of social systems. In neoclassical thinking, the sum of agents in the whole economy reflects its macroeconomic status. Therefore, the study of a representative agent should tell everything about the economy at the macro-level. However, studies of complex adaptive systems including in economics (Lengnick, 2013) show that the sum of separate individuals' characteristics does not equal to the status of the whole system, as microprocesses lead to emergent phenomena at the macro level.

ABMs were created later than DSGE and CGE models, thus, this class is still less developed and used than the previous two, but its usage is currently increasing. Lengnick (2013) distinguishes two types of ABMs: a) abstract (similar to the *Sugarscape* model by Epstein and Axtell (1996); Lengnick (2013)); b) data-driven models of specific economies (cf. Boero, 2015a; 2015b). The first class of models represents abstract economies with literature- or intuition-based values assigned to variables. The second class of models relies on economic data for a specific economy which it tries to model and then assesses behaviour of agents and outputs of calculated indicators based on various scenarios.

Instead of providing a system of stochastic equations that must then be solved, ABMs rely on heuristics. Each agent is assigned a particular set of defined actions and strategies that it carries out, interacting with other agents. Many steps of interaction periods are run, representing time flow, and provide a simulation of a real economy. The actions of agents are bounded by equations that define their behaviour. This allows the proponents of ABMs claim that their approach is built on microeconomic foundations more strongly and more realistically than the neoclassical models. Even very simple ABMs can capture some of the important economic laws/trends, e.g. Philip's and Beveridge's curves or economic cycles without introducing external shocks.

ABM-based analyses of the impact of economic policy are carried out both at the micro- and at the macro-levels. Such studies include assessing the impact agriculture policy (Happe, Balmann, Kellermann & Sahrbacher, 2008), public procurement, research, open standards (Malerba, Nelson, Orsenigo & Winter, 2008), and other policy areas. At the macro-level researchers analyse the impact of labour policy (Dawid, Gemkow, Harting & Nugart, 2012) fiscal (Morini & Pellegrino, 2015) and R&D policy (Russo, Catalano, Gallegati, Gaffeo & Napoletano, 2007). Thus, the strength of ABM approach is its flexibility to accommodate not only different kinds of policy but different levels of effects as well.

ABMs, that account for real economies, are used to assess specific public policy both *ex-ante* and *ex-post*. A good example of *ex-ante* assessment comes from Boero (2015b), where the impact of provision of broadband Internet in rural regions of Piedmont, Italy, is analysed. Using ABM allows the researcher to distinguish separate types of firms, analyse the impact of their spatial distribution based on type of land (urban, rural or intermediate) and proximity to other firms, and interactions between them in the supply chain, etc., which would not be possible with more common neoclassical macroeconomic models.

Another characteristic of ABMs important for this thesis is the ability to model government behaviour. While in the neoclassical models usually the differences in the constitutional order of a state can be accounted for by dummy variables in multiple linear regression models, ABMs could enable modelling government's behaviour based on the rules according to which its members are selected. The power of ABMs in such case was demonstrated by Boero (2015a) in his research on the economic impact of different-level government cooperation between Piedmont regional and Turin provincial governments. The model accounts for the interests of different governments to be re-elected, which influences their policy positions. The study finds that if industrial policy is coordinated on both levels, employment could be increased. However, differing incentives for governments do not allow achieving perfect coordination.

To sum up, ABMs have several advantages over neoclassical models: a) more realistic assumptions; b) flexibility; c) ability to account for government actions based on their incentives. Modelling challenges differ from those arising in neoclassical macro-models, i.e. distinguishing acting agents, isolating specific actions of agents, defining behavioural constraints, or calculating the values of relevant variables.

Innovation policy can also be analysed in ABMs. This can be done by focusing specifically on innovation policy or technological change and technology diffusion. Therefore, both ABMs modelling impact of direct support for research and innovation, and ABMs modelling technological change and innovation diffusion could be used to see the impact of innovation policy. However, the present research relies on macro-level aggregate data, and due to limited information availability at the micro-level, it would not be possible to suitable identify agent-actions at the micro-level, and calibrate the model to reflect the real life processes. Yet, this approach could proof to be useful in future studies on the government behaviour in the context of electoral incentives.

Neural network models

The final methodological approach to be discussed in this chapter is neural network modelling. The basic logic behind it is related to that which is found in regression-based modelling. Specific explanatory variables are selected to predict the outcome variable. As such, it is possible to select economic growth rate as the dependent variable and explanatory variables such as investment to GDP ratio, population growth, school enrolment rates, etc., which come from neoclassical or endogenous economic growth theories. This also allows incorporating variables coming from the innovation systems approach. However, the crucial difference between growth regressions and neural network models is the use of hidden layer of variables in the latter.

Neural network approach has an advantage over ordinary linear regressions in that it allows modelling non-liner relationships and the relationship between a predictor and the dependent variables can acquire any functional form. Therefore, there is no need to transform variables to linearize them (Gonzalez, 2000). The method assesses the functional form through machine learning. To this end two sets of data are required, a training set on which the estimation is based and a test set for assessment of the accuracy of the generated model. Despite overcoming the issue of non-linearity, neural network models suffer from several significant problems. First, they are distanced away from theory. The relationships between variables are extracted based only on given empirical data that they are provided. Second, the generated model is functioning as a black box and it is very difficult to assess the specific relationships between particular variables (Gonzalez, 2000).

Although neural network models have gained considerable attention in finance research (cf. Trippi & Turban, 1992), this is not the case in macroeconomics. Nonetheless, there have been several attempts to use neural networks to model economic growth, most often with direct comparisons to linear regression models. Gonzalez (2000) tests the power of neural network models for macroeconomic analysis by applying it to forecasting of Canada's economic growth. The structure of the model was based on two nodes in the hidden layer as well as bias terms for hidden and output layers. Weight for each connection between explanatory variables, biases and hidden layers were then estimated. Similarly, Tkacz (2001**)** also studied growth of the Canadian economy by using neural networks approach. Both authors find support for the relevance of neural network models, as they do not provide lower reliability results than the linear regression models. At the same time, they also find it difficult to identify statistically significant difference between neural network and linear regression models. There are also studies that analyse macroeconomic phenomena other than growth by adopting neural networks models. Choudhary & Haider (2012) apply such model to forecasting inflation in 28 OECD countries. They find that neural networks models are better at forecasting than autoregressive models in more cases than the opposite. Thus, there is support to the use of neural networks as a method to forecast change in macroeconomic variables.

The issue then is the relatively low explanatory power of neural networks models, when it comes to theory-building and theory-testing. It appears that even proponents of neural networks approach see it as a supplementing instead of substituting method in macroeconomic analysis (Gonzalez, 2000). This is especially important in the light of variable choice – variables come from linear regression model, where they are chosen based on economic theory for applied research. Thus, while neural networks models may indeed serve as a very promising tool of analysis, for theoretical research these models are far less suitable, including for the present dissertation. Furthermore, data requirements to build reliable neural network models are high, which is limited to macro-level for indicators on innovation activities and their outputs. This limits the number of observations. Therefore, neural network approach has limited applicability for this dissertation.

2.2.3. Selecting Model Estimation Methodology

The review of methodological approaches to studying determinants of economic growth shows that there is a variety of approaches even though most research is dominated by regression-based growth econometrics. This opens possibilities for a more encompassing study, as suggested by Durlauf et al. (2004). The prevalence of regression analysis for cross-country research is not without good reasons. Table 7 lists the strengths and weaknesses of methodologies discussed in this chapter.

Table 7. Strengths and weaknesses of models for analysis of impact of innovation policy on economic growth

Model type	**Strengths**	**Weaknesses**
Growth regressions	Robust and well-developed methodology; allow clearly identifying impact of each explanatory variable; can include endogenous growth; less data-intensive, and cross-country, and time-series macro-level data are readily available for many countries	Low reliance of micro-foundations; assumption of linear or linearizable relationships between variables; do not allow extensive modelling of agent interactions
DSGE models	Rely on macroeconomic theory; provide clearly defined estimates of relationships between variables; various elements of an economy might be included into equation system; allow exploring impacts of many variables and future trends	Do not allow extensive of modelling agent interactions; macro-level results are obtained by aggregating micro-level results; impossible to thoroughly account for the effects of institutions; limited scope and due to uncertainty are less suitable for policy analysis than CGE models; difficult (although possible) to include endogenous technological growth; based on linear relationships
CGE models	Provide clearly defined relations between variables; rely on macroeconomic theory; theoretically consistent; various aspects of an economy might be included into equation system; often used and, therefore, constantly developed; allow modelling relationships between various sectors of the economy; often used for policy analysis; allow exploring economic impacts of many variables	Does not allow extensive of modelling agent interactions; macro-level results are obtained by aggregating micro-level results; impossible to thoroughly account for the effects of institutions; based on assumption that situation reflected by the data defines equilibrium; require huge amounts of data and resources to implement; limited use for forecasting in the long term; difficult (although possible) to include endogenous technological growth; based on linear relationships
ABM models	Fit evolutionary economic theory; fit innovation systems theory; allows modelling diverse agents and outcomes/impacts of their interactions; realistic transition from micro-foundations to macro-level; allow including different sectors of an economy; innovation policy and its dependence on constitutional setting of a country may be	Small inaccuracies at micro-level might lead to strongly incorrect predictions at macro-level; although suitable for policy analysis, this is a rather new field and models are not as developed and advanced as neoclassical macroeconomic models; open to Lucas critique; do not provide a single answer/ solution to the problem; difficult to find optimal routines for agent behaviour

	modelled as endogenous; allow spatial analysis	
Neural network models	Allow to include non-linear relationships; the model itself identifies the functional form of relationships; the impact of specific variables might be expressed through elaborate functional forms; model is adaptive and easy to modify	More difficult to assess impact of separate variables than in the case of other models; more difficult to establish relationship with economic theory than in the case of other models; do not model interactions of agents; optimal model is not necessarily found; require a large amount of data

There is no method without weaknesses to research of macroeconomic phenomena. While emerging agent-based models are very promising, they are still little developed to address very complex cross-country issues within a scope of a single dissertation. Meanwhile, another emergent method, namely, neural networks approach currently lacks development with respect to its possible theoretical contributions. This leaves using models based on either linear growth regressions or general equilibrium models. Given the data availability, the reliance of panel data involving many countries, and the reliance of innovation systems' view, the cross-country regressions are the most fitting approach due to reasons discussed above. In addition, it is easy to incorporate variables suggested by the innovation systems approach in to the equations, as long as a way to measure them is found. Therefore, further chapters and the empirical research are framed in the context of the growth regressions methodology.

2.3. The Approach to Assessing the Model Linking Electoral Institutions, Innovation Policy, and Economic Growth

This part so far has developed a theoretical model and identified the most relevant methodology for empirical research. After discussing the theoretical model and assessing the different methodologies that could be used for empirical estimation, it is necessary to define the specific strategy used to test the model empirically. Since the chosen methodological approach is cross-country growth regressions, the issues listed in Table 8 must be decided.

Table 8. Steps for estimating the proposed relationships

Area	Decisions
Hypotheses	Identifying hypotheses that are implied in the theoretical model
	Identifying the means to assess the hypotheses
The form of econometric model	Identifying, how innovation channels could be included in growth regressions
	Defining the system of econometric equations that can estimate the model and assess the raised hypotheses
Data management	Identifying the relevant data sources
	Defining procedure for data acquisition and structuring
	Identifying potential issues with the data and ways to overcome them
The scope of empirical study	Identifying the countries relevant for research that can be included in the sample
	Defining the time period to be covered in the dissertation research
Indicators	Assessing the possible ways to measure variables included in the model
	Selecting indicators that are the most suitable for this research

Accordingly, this chapter translates the conceptual model into an empirical model by providing a strategy for model estimation. The steps that already discuss specific data are covered in the Part 3 of the dissertation. This section covers the questions about the hypotheses, the econometric equations' system and the general use of econometric methods.

2.3.1. Hypotheses on the Links Between Electoral Systems, Innovation, and Growth

This section looks at the ways to identify the presented theoretical model, empirically. It covers hypotheses that can be extracted, and the econometric equations, on which the empirical estimation is built.

The model structure as outlined in Chapter 2.1, leads to three groups of hypotheses. The first group (H1) covers the innovation determinants of economic growth. Although there these relationships have been analysed (see discussion in Chapter 1), it is worth testing them here again to determine the baseline for the relationship between innovation policy and economic growth, which can then be assessed against the impact of different electoral systems. Since the study uses newly calculated indexes, testing the hypotheses may help validate them. The second group (H2) covers the determinants of innovation output. Finally, the third group (H3) covers the effect of electoral systems on three innovation channels. All in all, the following hypotheses are raised:

- H1. Determinants of economic growth:
    - H1.1. Increase in innovation output has a positive effect on economic growth.
    - H1.2. Increase in knowledge absorption has a positive effect on economic growth.
    - H1.3. Increase in technology transfer has a positive effect on economic growth.
- H2. Determinants of innovation output:
    - H2.1. Knowledge absorption has a positive effect on innovation output.
    - H2.2. Government knowledge creation has a positive effect on innovation output.
    - H2.3. Private knowledge creation has a positive effect on innovation output.
    - H2.4. Technology transfer has a positive effect on innovation output.
    - H2.5. Government knowledge creation has a larger positive effect on innovation output when the country has a proportional electoral system than when it has a majoritarian electoral system.
    - H2.6. Knowledge absorption has a larger positive effect on innovation output when the country has a proportional electoral system than in the case of a majoritarian electoral system.
    - H2.7. Technology transfer has a larger positive effect on innovation output when the country has a proportional electoral system than in the case of a majoritarian electoral system.
    - H2.8. Proportional electoral systems have a larger positive effect on innovation output in comparison to the majoritarian electoral systems.
- H3. Effects of electoral systems on the separate innovation channels:
    - H3.1. The majoritarian electoral systems have a larger positive effect on knowledge absorption in comparison to the proportional electoral systems.

- H3.2. The majoritarian electoral systems have a larger positive effect on technology transfer in comparison to the proportional electoral systems.
- H3.3. The majoritarian electoral systems have a larger positive effect on government knowledge creation in comparison to the proportional electoral systems.

In addition to defining ways to test the hypotheses, it is first important to determine the type of data that is the most relevant, taking into account that the growth regressions approach is used. First, it is clear that the cross-sectional dimension is necessary, because a variety of countries is needed to account for the differences in electoral systems. Second, since the analysis deals with change over a period of time (e.g. economic growth), time-series dimension must also be used. Although one of the main explanatory variables in this study, electoral systems, is time invariant, panel data analysis here is more suitable than cross-sectional, mainly because of the expected moderation effects, as implied by hypotheses H2.5, H2.6, and H2.7. This requires the inclusion of interaction terms between electoral system and other (continuous, time-variant) variables. Therefore, the longitudinal dimension can add more needed information.

Using panel data approach has several strengths compared to cross-sectional data:

- a higher number of observations than for only time-series or only cross-sectional data, although this is also needs to be treated with caution, as the inflation of the number of observation comes of observing the same cross-sectional units only at different time periods
- two dimensions of analysis, capturing variation among sections, but also accounting for variation in time
- accounting for unobserved heterogeneity, capturing the unobserved or wrongly measured effects, thus allowing a more precise estimation of the effect of selected independent variables on the dependent variable

Panel data can be studied using a variety of methods: pooled OLS, fixed effects, first differences, random effects, and weighted least squares. Each method has particular strengths and weaknesses, discussed in Table 9 below.

Table 9. Methods of panel data analysis

Method	Essence	Strengths	Drawbacks
Pooled OLS	Standard OLS procedure, does not account for the time-series dimension, treats each case as independent from others	Depending on the data structure can be adequate and easy to implement; can be used to estimate first differences model	Does not account for the longitudinal dimension of the data
Fixed effects	Estimates the coefficient based on within unit time-series data, thus, accounting for time-invariant factors associated with the unit	Helps to account for the unobserved heterogeneity	It is not possible to include time-invariant indicators
First differences	The dependent and each independent variables are recalculated by taking the difference between a value at a given time and a value at a previous point in time	Helps to account for the unobserved heterogeneity; diminishes trend effects	It is not possible to include time-invariant indicators
Random effects	Estimates the coefficient based on the weighted average of both within and between unit variation	Allows including time-invariant factors	Does not account for unobserved heterogeneity
Weighted least squares	Estimates coefficients based on weights given to observations based on their variance (higher weights are given to observations with low variance)	Allows including time-invariant factors; to resolve heteroskedasticity (including groupwise) problems	May estimate wrong weights; does not account for unobserved heterogeneity

Source: author's compilation based on Allen (2004); Gujarati (2004); Woolridge (2002).

Table 9 above lists the main characteristics of each panel data analysis method. Each has their own strengths and drawbacks. The pooled OLS method (including with panel data corrected standard errors) is an often used to analyse cross-sectional longitudinal data. However, it has a drawback, that it lacks insights into changes in variables within cross-sectional units, as it treats each observation separately. A related method, WLS, uses weights to account for error variance (including groupwise) and helps to solve the problem of heteroskedasticity. However, wrong estimates of weights can provide distorted results.

The fixed effects method is among the main means to account for the unobserved characteristics of cross-sectional units. Therefore, the estimations of this methods help to improve the accuracy of results. A significant drawback of the fixed effects method is that it requires independent variables to be time-variant. Time invariant variables are attributed to the unobserved characteristics of the cross-sectional unit. Similarly, first differences estimation cannot account for time invariant factors, as it also removes the effect of unobserved characteristics of a cross-sectional unit. As an additional advantage over the fixed effects method, first differences approach can help reduce the effects of non-stationarity in the longitudinal dimension of the data.

Finally, random effects model takes into account both within and cross-unit dimensions, which allows using time invariant variables in a model. However, this advantage comes at the cost of accounting for unobservable characteristics.

Since one of the main factors included in the study, electoral systems, is time-invariant, not all methods can be applied. Fixed effects and first differences models are not useful, when a model includes electoral systems (but may be used if a particular regression model does not incorporate electoral systems). The further model choice depends on data characteristics and tests associated with method choice, and it is further specified in the following chapters with empirical estimations.

For each constructed model, the following steps are taken, to ensure the validity of the approach:

1. Depending on variables used in a particular model, joint significance of differing group means (compares pooled OLS and fixed effects models), Breusch-Pagan (compares pooled OLS and random effects models), and Hausman (compares fixed effects and random effects models) tests are used to determine, which type of models is the most suitable. The decision is based on p-values of the respective tests, and the main model is chosen. Other models are also estimated in order to assess the sensitivity of obtained results. Their results are provided in Appendix 7.
2. In models, where time-invariant indicators are not included, first differences estimation is carried out for result comparison, using first order differences for all variables in the model. Pooled OLS estimation method is then used. Furthermore, first differences estimation makes the data stationary (Gujarati, 2004)

3. Multicollinearity is checked using the variance inflation factors' (VIF) calculation, where multicollinearity is considered if VIF for an indicator is > 10. Variables with values above 10 are removed (one by one, testing different combinations), except in cases, where interaction variables are included in the model, because they always cause VIF to increase (Gujarati, 2004).
4. Autocorrelation is checked using Durbin-Watson statistic, where values between 1.5 and 2.5 indicate that autocorrelation is not problematic. Other values show either positive or negative autocorrelation. In case there is autocorrelation, heteroskedasticity and autocorrelation consistent (HAC) standard errors are used based on Newey-West approach (Newey & West, 1986), also described in Gujarati (2004).
5. Normality of residuals is checked via a chi-square test. The decision is made based upon the test's p-value, where $p < 0.05$ shows that residuals are not normally distributed. However, due to the relatively large number of observations and the implication of the central limit theorem, even if residuals are not normally distributed (Sirkin, 2006), it is not a significant problem for a model.
6. Heteroskedasticity is checked via White's test. If the $p < 0.05$, HAC standard errors are used based on Newey-West approach (Newey & West, 1986). Additionally, all models are tested for groupwise heteroskedasticity using Wald's test. If this problem is located, results are double-checked with results obtained from respective groupwise WLS model results provided in Appendix 7.
7. Inclusion of time dummies depends on model fit results. The main models are estimated both with time dummies and without them. The models are then compared based on two goodness of fit indicators: log likelihood and Akaike information criterion. The model with better results is then used for the analysis (Gujarati, 2004). Appendix 8 provides results for comparison.
8. Country dummies are not used in the study, because electoral systems variable is time-invariant. Where no time-invariant variables are used, fixed effects and first differences models account for country specific factors, eliminating the need for country dummies.
9. Lagged variables are included, based on the model goodness of fit criteria,

such as log-likelihood and Akaike information criterion. Introduction of lag is necessary due to the considered temporal relationship – the past values of independent variables affect the present.

Given the choice of panel data analysis as the empirical estimation tool, the hypotheses and their assessment are described in greater detail below.

Increase in innovation activities and output will lead to increase in economic growth (H1.1, H1.2, H1.3)

As postulated in the theoretical model (Chapter 2.1), innovation policy should affect economic growth positively, this includes three hypotheses:

- H1.1 Increase in innovation output has a positive effect on economic growth
- H1.2 Increase in knowledge absorption has a positive effect on economic growth
- H1.3 Increase in technology transfer has a positive effect on economic growth.

The hypotheses will be tested by assessing panel data with the help of a regression model in the following form:

$$Y_{i,t} = \beta_0 + \sum_{x=1}^{3} \beta_x \; X_{i,t} + \sum_{z=1}^{n} \gamma_z \; Z_{i,t} + \varepsilon_i \text{ (2.10.)}$$

Here, *Y* is the dependent variable, economic output; *X* is a set of hypothesized explanatory variables representing innovation output, knowledge absorption, and technology transfer. Finally, *Z* is a set of control variables. The following variables describing innovation policy are expected to have positive effect on economic growth:

- Innovation output index. It is expected its increase will lead to increase in *Y*.
- Technology transfer index. It is expected that its increase will lead to increase in *Y*.
- Knowledge absorption index. It is expected its increase will lead to increase in *Y*.

As the hypotheses state, the increase in these variables will lead to positive change in economic output. Therefore, a first differences equation will also be used to test the hypotheses (the notation remains similar as in equation 2.10.).

$$\Delta Y_{i,t} = \beta_0 + \sum_{x=1}^{3} \beta_x \; \Delta X_{i,t} + \sum_{z=1}^{n} \gamma_z \; \Delta Z_{i,t} + \varepsilon_i \text{ (2.11.)}$$

Each hypothesis will fail to be rejected if the coefficients are positive and statistically significant. Therefore:

- H0 – β_x =< 0 and p =< 0.1; or p > 0.1

- H1.1, H1.2, and H1.3 – $\beta_x > 0$ and $p < 0.1$.

The factors affecting innovation output

Following the logic discussed in Chapter 2.1, it is expected that innovation output depends on innovation policy, innovation activities, and electoral systems. Accordingly, two types of hypothesis have been raised – first, the hypotheses of direct effects and, second, hypotheses of interaction effects. The first set of hypotheses is as follows:

- H2.1 Knowledge absorption has a positive effect on innovation output
- H2.2 Government knowledge creation a has positive effect on innovation output
- H2.3 Private knowledge creation has a positive effect on innovation output
- H2.4 Technology transfer has a positive effect on innovation output
- H2.8 Proportional electoral systems have a larger positive effect on innovation output compared to the majoritarian electoral systems

This presupposes the following type of regression to assess the hypotheses:

$$\sum_{i=1}^{j} Y_{i,t} = \beta_0 + \beta_1 \quad D_{i,t} + \sum_{x=1}^{n} \zeta_x \quad X_{i,t} + \sum_{z=1}^{n} \gamma_z \quad Z_{i,t} + \varepsilon_i \text{ (2.12.)}$$

In this case the dependent variable *Y* represents innovation output. D_i is a time-invariant dummy variable indicating, which electoral system that is used in country *i*, *X* is a set of the independent variables reflecting knowledge absorption, government knowledge creation, private knowledge creation, and technology transfer. Finally, *Z* is a set of relevant control variables.

The hypotheses will be failed to reject if at least one of the independent variables from set X is not equal to zero. Therefore:

- H0 – ζ_x =< 0 and p =< 0.1; or p > 0.1 // β_1 =< 0 and p =< 0.1; or p > 0.1
- H2.1, H2.2, H2.3, and H2.48 – $\zeta_x > 0$ and $p < 0.1$
- H2.8 – $\beta_1 > 0$ and $p < 0.1$

The second set of hypothesis is as follows:

- H2.5 Increase in government knowledge creation has a larger positive effect on innovation output if a country has proportional electoral system than if a country has a majoritarian electoral system
- H2.6 Increase in knowledge absorption has a larger positive effect on innovation output if a country has proportional electoral system than if a country has a majoritarian electoral system

- H2.7 Increase in technology transfer has a larger positive effect on innovation output if a country has proportional electoral system than if a country has a majoritarian electoral system

These hypotheses require introduction of interaction terms to isolate effect of innovation policy on economic growth under different electoral systems. For each of the case where electoral systems were found theoretically to have impact on innovation policy (see Chapter 2.1), an interaction term is added. This leads to the following equation to be estimated:

$$\sum_{i=1}^{j} Y_{i,t} = \beta_0 + \beta_1 \quad D_{i,t} + \sum_{x=1}^{n} \zeta_x \quad X_{i,t} + \sum_{w=1}^{n} \eta_w X_{i,t} * D_{i,t} + \sum_{z=1}^{n} \gamma_z \quad Z_{i,t} + \varepsilon_i$$

(2.13.)

In this case, *Y* represents innovation outputs, D_i is a dummy variable for electoral system, *X* - independent variables defining innovation policy and innovation activities, while *Z* is a set of control variables, and $X*D_i$ stands for the interaction between electoral system and innovation policy / innovation activities variables. The following effects are expected:

- H0 – $\eta_w + \zeta_x =< \zeta_x$ and p =< 0.1; or p > 0.1
- H2.5, H2.6, and H2.7 – $\eta_w + \zeta_x > \zeta_x$ and p < 0.1.

If H2.5, H2.6, and/ or H2.7 are true, then electoral systems indeed affect growth through affecting innovation policy channels, as expected from the literature analysis and theoretical modelling, discussed in depth in Chapter 2.1.

The direct effects of electoral systems on innovation

The theoretical model suggests that electoral systems affect all three types of innovation policy channels – government knowledge creation, knowledge absorption, and technology transfer. The related hypotheses drawn from the model are:

- H3.1 Majoritarian electoral systems have a larger positive effect on knowledge absorption compared to the proportional electoral systems
- H3.2 Majoritarian electoral systems have a larger positive effect on technology transfer compared to the proportional electoral systems
- H3.3 Majoritarian electoral systems have a larger positive effect on government knowledge creation compared to the proportional electoral systems

In order to test the hypothesis, the following type of regression must be used:

$$Y_{i,t} = \beta_0 + \ +\beta_1 \quad D_{i,t} + \sum_{z=1}^{n} \gamma_z \quad Z_{i,t} + \varepsilon_i \quad (2.14.)$$

In this case, Y represents economic growth or total factor productivity, D_i is a dummy variable for electoral system, and Z stands for a set of control variables.

It is expected that proportional electoral system has positive effect in terms of H3.1 and H3.2 but not H3.3. Therefore:

- H0 – β_1 => 0 and p =< 0.1; or p > 0.1
- H3.1, H3.2, H3.3 $\beta_1 < 0$ and $p < 0.1$

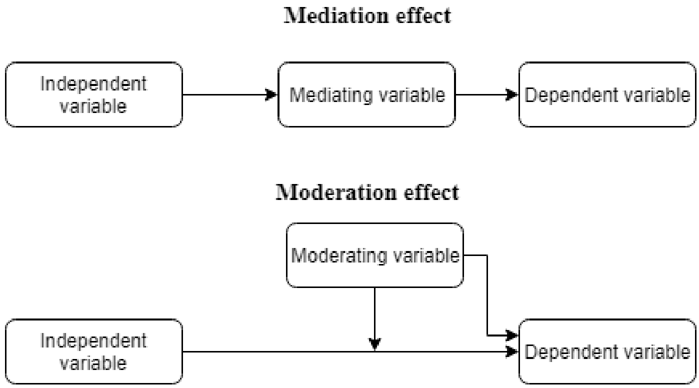
If H3.1, H3.2, or/ and H3.3 is true, then electoral systems indeed affect innovation policy, as expected from the literature analysis and theoretical modelling.

2.3.2. Econometric Equations System for the Assessment of the Theoretical Model

The chosen cross-country growth regressions methodological approach and the outlined tests for hypotheses suggest that a system of regressions must be developed. The structure of the theoretical model implies that some dependent variables can also be endogenous to the model. Therefore, the system must be able to establish the indirect effects of certain variables (e.g. the effect of electoral systems on innovation output through knowledge absorption). This can be implemented via connecting equations by using the same variable as dependent in one equation and as independent in another on. The indirect relationships are understood as mediation. Figure 4 below shows how mediation works.

Another important implication of the model is that certain variables have joint effects (e.g. the effect of knowledge absorption on innovation output, when there is a particular electoral system in place). The equation system must also include such relationships between variables as defined in the theoretical model. This can be implemented by including interaction terms between different variables. Such relationships are understood as moderation. Both of these two types of impacts are relevant for the present research, and the approach proposed below allows distinguishing both of them. Moderation is covered by an equation system, which has dependent variables treated as endogenous in the model. Mediation is covered by using interaction variables between electoral systems and other variables of interest, as suggested by the theoretical model.

Figure 4. Moderation and mediation effects



The first equation defines the drivers of GDP / economic growth (calculating the first difference of the dependent variable):

$$\ln(GDP)_{i,t} = \beta_0 + \beta_1 \ln(GFC)_{i,t} + \beta_2 L_{i,t} + \beta_3 IO_{i,t} + \beta_4 TT_{i,t} + \beta_5 KA_{i,t} + \varepsilon_{i,t} \quad (2.15.)$$

Here, *GDP* stands for the economic output, *GFC* – the gross capital formation, *L* – the labour force, *IO* – the innovation output index, *TT* – the technology transfer index, and *KA* – the knowledge absorption index, *i* is country, and *t* – year. It enables assessing hypotheses H1.1, H1.2, and H1.3. Additionally, models in first differences should be formed to capture the relationship between changes in the variables, showing if change in innovation indexes leads to change in GDP level.

$$\Delta\ln(GDP)_{i,t} = \beta_0 + \beta_1 \Delta\ln(GFC)_{i,t} + \beta_2 \Delta L_{i,t} + \beta_3 \Delta IO_{i,t} + \beta_4 \Delta TT_{i,t} + \beta_5 \Delta KA_{i,t} + \varepsilon_{i,t}$$

(2.16.)

The second equation defines the determinants of innovation output:

$$IO_{i,t} = \beta_0 + \beta_1 KA_{i,t} + \beta_2 GC_{i,t} + \beta_3 TT_{i,t} + \beta_4 PC_{i,t} + \beta_5 EL_i + \beta_6 KA_{i,t} * EL_i + \beta_7 GC_{i,t} * EL_i + \beta_8 TT_{i,t} * EL_i + \varepsilon_{i,t} \quad (2.17.)$$

Here, *IO* stands for innovation output, *KA* – knowledge absorption, *GC* – government knowledge creation, *TT* – technology transfer, *PC* – private knowledge creation, and *EL* – electoral system, *i* – country, and *t* – year. This equation tests hypotheses H2.1, H2.2, H2.3, H2.4, H2.5, H2.6, H2.7, and H2.8.

Finally, three equations are used to establish, whether electoral system affects each innovation channel:

$$KA_{i,t} = \beta_0 + \beta_1 EL_i + \varepsilon_{i,t} \quad (2.18.)$$

$$GC_{i,t} = \beta_0 + \beta_1 EL_i + \varepsilon_{i,t} \quad (2.19.)$$

$$TT_{i,t} = \beta_0 + \beta_1 EL_i + \varepsilon_{i,t} \quad (2.20.)$$

Here, *KA* stands for knowledge absorption, *GC* – government knowledge creation, *TT* – technology transfer, and *EL* – electoral system, *i* – country, and *t* – year. They assess H3.1, H3.2, and H3.3.

These regression equations (and their derivatives in first differences) fully reflect the model proposed in Chapter 2.1, and are used to assess the hypotheses empirically in the following part of the dissertation.

In order to finalise the model, it is important to select specific indicators. Here, it is important to define how the innovation channels are assessed. The proposed approach is to construct indexes around these channels. This helps to achieve the following goals:

- To simplify the equation system and facilitate the interpretation of results by providing a single variable per construct rather than a complex set of interrelated simple indicators.
- To decrease the multicollinearity between explanatory variables, by using their unique elements to develop indexes.

The obvious limitation is that using indexes hides the role of individual simple indicators. However, it allows to better capture the tendencies in the specific innovation channels, including the role of moderation of effect by electoral institutions.

Methodological limitations

The proposed methodology has several limitations that must be taken in mind, when considering the results of the study:

1. The research uses aggregate macro-level data and certain simplification of micro-level processes related to innovation policy is evident. Therefore, not all specific mechanisms through which the impact of innovation policy manifests can be captured in the study in a detailed way, as the analysis is not carried out at the policy instrument level. However, the research problem and its application to cross-country data sample dictates the available comparable macro-level data. Analysis specific innovation policy instruments could be one of the areas for future research.
2. Certain innovation channels are expressed through economic outcomes instead of specific policy actions. This limitation comes from the limited number of cross-country indicators that can capture policy intensity. Therefore, to an extent the study is bounded by indicators and their indexes,

which are available for many countries and with a sufficiently long time-series. Nonetheless, the outcomes allow identifying the economic effects of electoral institutions, which allows relating them to policymaking, thus, policy dimension is not lost.

3. The approach to economic growth focuses on economic performance and its change. This allows measuring shorter term effects, how change in innovation indicators affects economic growth from one time period to another. However, this approach allows to capture the change in output associated with change in innovation variables and to diminish the effects of diminishing returns on growth, where countries have reached stable growth trajectories. It also helps to diminish the effect of country size (larger countries may be less affected by higher absolute values of used indicators), because change in innovation indicators is regressed against percentage change in economic growth.
4. In some cases, when only time-invariant variables are used, panel data provides an inflation of the number of cases, increasing the number of observations due to the longitudinal, but not due to the cross-sectional dimension. Therefore, the result sensitivity is assessed with additional models provided in Appendix 7.
5. The regression-based approach provides more information about the correlation than causation among variables. To an extent inclusion of lags helps to ensure the direction of effects, but does not provide full evidence of causality. However, this problem does not affect the impact of electoral systems, since the direction of effect is clear here. They are time-invariant and were adopted before the time period used for the empirical analysis. Therefore, variables affected by electoral systems cannot affect them, as there are no reasonable grounds to expect an opposite effect. Future research, could focus on more specific and less complex conceptual models, but incorporate Granger causality or other tests to further assess if the direction of effects found in this study holds true.

2.3.3. Data Collection and Cleaning Routine

Data collection methods are suggested by methods to be used in research. The following steps are envisioned:

- Identification of relevant databases. Time scope and geographic coverage of the available data were assessed to choose between alternatives if more than one comprehensive database is found.
- Automatisation of data downloading and formatting. In order to minimise the possibility of human error and mistakes in data collection. In the case, where data could be obtained in XML format, a specific code in R was written to automatically extract the data to the programming environment, and convert it into a wide-format panel data, if required (e.g. this is the case with OECD data).
- Data was merged to reflect similar topics (e.g. a separate matrix with data on R&D, a separate matrix for data on growth, etc.). This will ensure that:
    - it is easy to navigate
    - matrices do not get too large, thus avoiding computational overloads
- A framework for working with relational datasets was prepared, so that there are separate matrices sharing same country and year variables for easy computations.
- Missing data was imputed to expand the number of observation.

These steps ensure that data are as consistent as possible, easily accessible and navigable, meets the technical requirements for methodologically valid analysis.

As discussed in the previous chapters, innovation policy cannot be directly measured due to its complexity. Therefore, several composite index variables are distinguished, to include the simple variables selected as reflecting particular dimensions of innovation policy.[19] The choice of included variables is theory-driven, instead of taking the whole sample of indicators and extracting the main components stemming from them. First, the underlying latent variable is determined (based on the theoretical model developed in Chapter 2.1). Second, available simple indicators are attributed to a specific category.

[19] New indexes are developed instead of using existing ones, such as the global innovation index due to the often happening changes in their construction methodology, and often used expert insights, which increases biases of such indicators. The pre-developed indexes also use lagging data quite often. For example, the 2019 European Innovation Scoreboard uses data from 2016 to account for scientific publications or patent applications (Hollanders, Es-Sadki & Merkelbach, 2019). This limits the usefulness of such composite indexes, because they cover data from different time periods, making it difficult to assign a particular value of the whole index to a specific year.

The choice of indicators to be used in the model is important, since they can either provide support for hypotheses or falsify them, or be unfit to capture expected effects. This discussion is structured along the four main lines: a) indicators of economic growth; b) indicators of innovation policy; c) indicators of electoral systems; d) indicators for other variables.

Economic growth and innovation output. Two types of economic growth data are used, one in levels, and one in first differences, the latter to measure annual changes in the economic output. In both cases real GDP instead of nominal GDP values are taken. The data are also calculated both as a total and as a per capita (per unit of labour force (ALF)) measure. Although it is expected that innovation policy will affect economic growth through affecting TFP, this variable cannot be directly measured. However, because economic growth is already measured, there is neither way nor need to include total factor productivity as a separate indicator. The effects of labour and capital are included separately. It is assumed that part of TFP will be captured by the innovation output index variable, which will help to identify the effect. The innovation output indicators cover both academic research outputs and patents.

Innovation policy. For the purposes of this dissertation, different innovation channels are to be measured – government knowledge creation, technology transfer, and knowledge absorption. Together these indicators provide a composite view of innovation policy (according to its broad conception). They will allow measuring the effect of government on knowledge creation, technology transfer, and knowledge absorption through developing respective index variables. Here, the main challenge is to identify policy-relevant variables. In the case of government knowledge creation, the choice is evident – the chosen variables directly reflect government investment in R&D activities. While it would be beneficial to also add tax incentives, existing data availability and limitations do not allow including this variable in the study.

The knowledge absorption and technology transfer policies are more difficult to measure directly. To overcome this challenge, policy outcome measures are used. Since knowledge absorption and technology transfer do not directly “create” innovation, the levels of indicators related to knowledge absorption and technology transfer can be used. For example, if country’s FDI (a channel for technology transfer) is affected by the electoral system, it suggests that FDI (and through it technology transfer) is related to government behaviour as captured by used indicators. Therefore, for knowledge absorption and technology transfer, outcome variables are used.

Variables used are measured in relative or absolute values. This helps to capture both the relative role of innovation policy, but also the overall scope of innovation channels. This is an important dimension, since the output of innovation as measured by patenting and research, is also captured in absolute terms. Furthermore, the amount of output is important in how important it is for the economy, also increasing chances of breakthrough innovation, which could not be captured by relative measures.

Electoral systems. There are several ways to measure the type of electoral system. The first one is to isolate countries which have either proportional or majoritarian systems, and create a dummy variable for it. This is the way of measuring that is chosen for the empirical analysis. Mixed-systems are disregarded in such case. Milesi-Ferreti, Perotti and Rosagno (2002) also propose including average standardized district magnitude, average district magnitude and average deviation from proportionality as potential alternative indicators. There is reasonable criticism of using dichotomous measure (Rickard, 2017; Taagepera, R., & Qvortrup, 2012), but its relevance depends on the context. The focus of the present study is strictly on the government-incentives based on geographic dimension of election. For this reason, a dichotomous measure works, even if there is variation in electoral specifics within country groups.

Control variables. Control variables are dictated by theory. The indicators for control variables are as follows:

- Capital. As explained by the neoclassical economic theory, capital is one of the most important factors explaining variation in economic growth. It is calculated in real terms.
- Labour. Labour is another of the main engines of growth from the neoclassical growth models. It is measured as the stock of persons in the labour force.

Private R&D spending. In many advanced countries the majority of R&D is funded by business sector. Therefore, it is important to include it as an additional innovation-related factor when explaining economic growth and change in innovation output.

Table 10 below connects the indexes with specific variables and comments on their relation to innovation policy.

Table 10. Indexes and simple variables

Index variable	Manifest variable	Comments on relation to innovation policy
Government knowledge creation	Gross expenditure on R&D	The innovation policy is reflected via government expenditure on R&D and gross budgetary appropriations and outlays for R&D. The gross expenditure on R&D helps to capture the overall R&D expenditure since government actions may also affect the total.
	GERD as % of GDP	
	Basic research as % of GERD	
	GERD per capita	
	Government funded GERD %	
	GBAORD	
Innovation output	Number of triadic patent families	Innovation output is calculated based on two types of products of the innovation activities. First, it includes data on publications as the output of research. Second, it includes the number of patents as a part of final innovation activities related to commercialisation. These are likely to be affected by innovation policy indirectly, through knowledge creation, technology transfer, and knowledge absorption, as implied by the model.
	Number of publications	
	Publications per researcher	
	Total number of citations	
	Citations per document	
	H-Index	
Technology transfer	R&D expenditure of foreign affiliates	The innovation policy in the technology transfer index is captured indirectly through policy outcome proxies. There are no indicators that could capture the policy for technology transfer directly, therefore, the outcomes associated with technology transfer are assumed to capture the effects of policy as well.
	Technology balance of payments	
	FDI inflows	
	FDI outflows	
	Imports	
	Exports	
Knowledge absorption	Total number of researchers full-time equivalent	The innovation policy in the knowledge absorption index is captured indirectly through policy outcome proxies. There are no indicators that could capture the policy for knowledge absorption directly, therefore, the knowledge absorption outcomes are assumed to capture the effects of policy as well.
	Researchers per thousand labour force	
	Researchers per thousand employment	
	Population with tertiary education	
	Population with population	

	attending no more than secondary education	
Private knowledge creation	% of GERD financed by industry	The index of private knowledge creation reflects the investment of business entities into innovation activities. They are expected to affect the innovation output index, as implied by the provided theoretical model.
	Business expenditure on R&D	
	BERD as % of GDP	
	BERD financed by BES %	

Note: IPR indicator has not been included due to its ambiguous effect (see Chapter 1.1), and crossing into several composite indicators (government knowledge creation, private knowledge creation, technology transfer).

In order to better reflect each of these categories, indexes have been calculated. Although, a broader variety of simple indicators could improve the accuracy of indexes, data availability limited the simple indicators that could be included. In addition, expanding the scope of simple variables would mean greater correlations within them, giving boundaries to the possible improvements. In order to prepare the data for constructing indexes, the following steps have been taken:

- It was made sure that all missing data points have been imputed for all the relevant simple indicators, following the procedure described above.
- The variables have been log-transformed, where they have been expressed in absolute values rather than percentage values.
- In cases with negative values (e.g. it is possible to have negative FDI indicators) and log-transformation, the whole variable was additionally transformed by adding the module of the lowest value plus one to each observation plus one.[20] This ensured that log-transformation was possible to carry out for the whole data sample.
- All simple variables used to construct indexes have been z-transformed to make sure that they have similar scale and can be used together to build a single indicator. In this way, the scale of a particular variable does not bias

[20] For example, the lowest value for an indicator is -100. Then, 101 would be added to each observation of the said indicator both cross-sectionally and longitudinally, to ensure that logarithmical values can be calculated.

the value of the index, i.e. no single simple indicator distorts the final outcome.

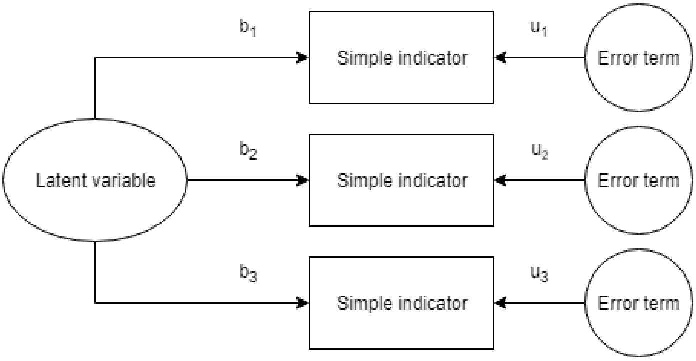
- The variables have been checked for the direction of their effects. That is, the higher the value of a particular variable, the more it should be associated with higher index values according to theory.
- The variables measure related objects, therefore, collinearity may be a risk. Belsley-Kuh-Welsch test for collinearity was implemented for manifest variables used to develop each composite indicator (Adkins, Waters & Hill, 2015). Although there were cases of moderately strong collinearity (condition value between 10 and 30), neither strong near dependences (condition value 30-100) nor very strong near dependences (condition value above 100) were identified and eigenvalues did not reach zero, making index calculation possible.

The method for calculating indexes has been chosen after a careful analysis of the available options. Several types of composite index computations have been considered. Overall, the methods can be split into two broad groups – frontier and non-frontier. Frontier (also known as the Benefit of Doubt approach) index computation is based on the Data Envelopment Analysis. The method has the advantage of endogenous determination of weights, it is easy to understand, and it is weak monotone (Fusco, Vidoli & Sahoo, 2018). Non-frontier methods are broad, and include factor analysis, principle component analysis, and other methods.

Due to the logic of the analysis, the non-frontier methodological approach has been chosen. More specifically, factor analysis has been used because it allows reconstructing a latent variable behind the used simple indicators. The logic of the composite indicators is that they reflect the underlying variable that cannot be directly measured. In this case, it is government's propensity to get involved in knowledge creation, the state of knowledge absorption and technology transfer, innovativeness (through output), and business propensity to get involved in knowledge creation,

The assumptions behind factor analysis are that data are structured around underlying factors and that data variance can be decomposed. The factor analysis presupposes a latent variable reflected by a set of simple indicators, which follows the logic described above. The factor (i.e. the latent variable) then shows itself through manifestations of simple indicators, which are understood as the causes of the latent variable. For example, R&D spending by the government is higher, if the government's propensity and capacity to create knowledge is higher. Figure 5 below illustrates this concept. Another assumption made in this study is that pooled data can be used (i.e. treating each observation as separate), increasing the total number of observations even if losing the time-dimension.

Figure 5. The logic of factor analysis.



Source: adapted from Matsunaga (2010).

An alternative method, principal component analysis approaches the same issue of finding a common factor behind many indicators from the opposite perspective. There, the derived index is a result of the used simple indicators, rather than the opposite. Therefore, such approach would not fit the logic of this thesis. In this research, the indexes represent latent variables and cause the observable variables rather than vice versa, and factor analysis is more suitable than principal component analysis.

As reflected in Figure 5, this approach reflects the ideas behind the current research, since the proposed index variables are interpreted as causing the simple variables. That is, the government knowledge creation, technology transfer, and knowledge absorption latent variables can be considered as inclinations – inclination for government to create knowledge, inclinations for government to encourage technology transfer and knowledge absorption. Private knowledge creation is the inclination of business sector to innovate. Finally, innovation output index is the overall innovativeness of the country. In this respect each of the indexes / latent variables is a cause of manifest simple variables. For example, business inclination to innovate causes businesses to spend on R&D. Therefore, the factor analysis was favoured over the principle component analysis.

The factor analysis of the indicators listed in Table 10 was implemented using the Compind package (Fusco et al., 2018) in the R programming environment. It calculated the factors and assigned the weights for each simple indicator within each index and then assessed the composite index values. The approach is outlined in OECD & JRC (2005). The factor analysis can be described by the following formulae:

$$x_1 = \alpha_{11} F_1 + \alpha_{12} F_2 + \cdots + \alpha_{1m} F_m + e_1$$

$$\ldots \qquad (2.21.)$$

$$x_q = \alpha_{q1} F_1 + \alpha_{q2} F_2 + \cdots + \alpha_{qm} F_m + e_q$$

Here *x* stands for z-transformed simple indicators variables, *α* are factor loadings relating factors *F* to the variable *X*, while *e* are independently distributed factors with zero mean (OECD & JRC, 2005). Thus, for each composite index factor loadings are calculated, and based on the selected number of dimensions, the composite index calculated. There is a variety of rules of thumb concerning the selection of the number of dimensions. To reduce subjectivity, using the prebuilt function in the Compind package, the value of the index was estimated based on each component's score weighted by its proportion variance. Therefore, if the proportion variance is low, the factor has little impact on the final value of the composite indicator, but all information from the simple indicators is retained. Since the goal is to create a composite indicator to be used in regression analysis rather than explain the underlying structure of the data or factors, it is deemed acceptable. This finalises the data construction and leads to empirical analysis described.

3. ASSESSMENT OF THE EFFECT OF INNOVATION POLICY ON ECONOMIC GROWTH IN THE CONTEXT OF ELECTORAL INSTITUTIONS

3.1. Defining the Extent of the Analysis of Links between Electoral Systems, Innovation, and Economic Growth

3.1.1. The Sample and Coverage of the Empirical Study

Considering the available information, the sample for the empirical consists of mainly OECD countries. This choice was made due to the following reasons:

- The need to cover a relatively homogenous sample of countries. There are two reasons for the focus on homogeneity of studied countries:
    - Discussion in Chapter 1.2 shows that the effects of innovation policy may differ based on the development level of the country. Therefore, studying countries at highly different levels of development could potentially hide the effects, limiting the relevance of the research.
    - The quality of governance institutions might vary significantly depending on the country. This could potentially hide the effects of the electoral systems, limiting the relevance of the research.

Choosing OECD countries at least to an extent satisfy these two conditions, as there are both political and economic requirements for a country to become a member of the OECD. The need to include countries with differing electoral systems. When choosing between OECD and Eurostat datasets, it is clear that the choice must be done considering the institutional suitability of OECD and EU Member States. In this case OECD is more suitable, as only the UK in the whole EU has the majoritarian first-past-the-post electoral system; other Member States use either proportional or mixed electoral systems. Therefore, it would not be possible to fully test the hypothesis using only the EU as the focus of empirical study. However, Romania is included as a prospective member of OECD. Even in the case of OECD the sample is limited, but the case, where one dummy variable is only positive for a single country, would be unacceptable from the methodological point of view.

The need for high quality time-series data on innovation policy. This leaves most of the developing countries out of the scope of this research because trustable data are limited and is likely to be available only for a limited time period. The two most extensive cross-country datasets are constructed by OECD and Eurostat. Both of them could theoretically be used for the empirical analysis, but given the choice of OECD countries, OECD is considered the primary dataset.

The reasons listed above support the choice of OECD countries as the sample. Since OECD also has one of the most data-rich country-level databases, OECD Main Science and Technology Indicators database (OECD, 2018) is used to collect data. The countries for which the data are available are as follows. Countries with proportional representation system are: AUT, BEL, CHE, CZE, DEU, DNK, ESP, EST, FIN, GRC, HUN, IRL, ISL, ITA, LUX, NLD, NOR, NZL, POL, PRT, ROU, SVK, SVN, SWE. Countries with majoritarian electoral systems are: CAN, GBR, USA[21].

Time series differ in length for separate countries. Although for some of the countries data are available since 1990s or even 1980s, it is not so for others. Furthermore, some variables have data only since 2000s. Given the limitations imposed by the data availability, the empirical analysis sample includes OECD countries from 2000 until 2014, leading to over 400 observations. It should also be stressed that countries mixed electoral systems (combining elements of majoritarian and proportional rules) have been removed due to potentially ambiguous effect, since they may provide mixed incentives for governments. They could, however, form a part of further research. Additional data concerning other variables is collected from the Comparative Political Dataset (Armingeon, Wenger, Wiedemeier, Isler, Knöpfel, Weisstanner & Engler, 2019) and SCImago (SCImago, n.d.) databases. The following section discusses the final selection of indicators and data sources.

3.1.2. Simple Indicators and Their Data Sources

After defining the scope of the study, it is possible to identify specific data sources for each indicator identified in Section 2.3, based on what data are available. The results of the analysis of the relevant databases point to several directions,

[21] Although the sample sizes for the two groups of countries differ and this must be taken into account, when interpreting the results, the analysis is possible. Unequal group sizes may introduce heterogeneous error variance (Shieh, 2018), however it can be overcome by using weighted least systems approach (Overton, 2001). Groupwise weighted least squares estimations were used, with results presented in Appendix 7 as additional models. As can be seen, results differ only slightly from the main models. The countries with majoritarian electoral systems all belong to the Anglo-Saxon tradition of law, and it could be reasoned that other factors can make them closely similar. However, if we look at the political dimension, the countries differ in terms of being federal / unitary, presidential / parliamentary, codified / non-codified constitutions. Therefore, these countries are considered heterogenous enough that the effect of electoral system could be distinguished. A similarity is the relatively low number of effective parties, but this is one of the outcomes of having a majoritarian electoral system.

important for finalising the indicator choice. Given the structure of the model (see Chapter 2.1) and the discussion on the types of indicators above, the variables to be included are listed in Table 11.

Table 11. Variables and data sources

Variable	**Data source**
GDP in PPP (millions USD)	OECD Database
Labour force (thousands)	OECD Database
Gross fixed capital formation (millions USD)	OECD Database
Gross expenditure on R&D PPP (millions USD)	OECD Database
GERD as % of GDP	OECD Database
Basic research as % of GERD	OECD Database
GERD per capita in PPP (USD)	OECD Database
Government funded GERD %	OECD Database
GBAORD in PPP (millions USD)	OECD Database
Number of triadic patent families	OECD Database
Number of publications	Scimago Database
Publications per researcher	Scimago Database
Total number of citations	Scimago Database
Citations per document	Scimago Database
H-Index (time invariant)	Scimago Database
R&D expenditure of foreign affiliates in PPP (millions USD)	OECD Database
Technology balance of payments in PPP (millions USD)	OECD Database
FDI inflows (millions USD)	OECD Database
FDI outflows (millions USD)	OECD Database
Imports (millions USD)	OECD Database
Exports (millions USD)	OECD Database
Total number of researchers full-time equivalent	OECD Database
Researchers per thousand labour force	OECD Database
Researchers per thousand employment	OECD Database
Population with tertiary education	CPDS Database
Population with no more than secondary education	CPDS Database
Electoral system (dummy, 0 – majoritarian; 1 - proportional)	CPDS Database
% of GERD financed by industry	OECD Database

Business expenditure on R&D in PPP (millions USD)	OECD Database
BERD as % of GDP	OECD Database
BERD financed by BES (%)	OECD Database

A review of the available indicators and their coverage indicated that there is an issue of missing data for some of the variables. To overcome this challenge, data imputation must be implemented, to improve the dataset and retain the number of observations. The following Section 3.1.3 addresses this issue by describing the methods and processes used for missing data imputation.

3.1.3 Imputation of Missing Data

After data have been obtained and merged into a single connected dataset, data cleaning and transformation required an additional step, the imputation of missing data. Data on innovation is difficult to find, and often specific variables have missing data points. This is an obvious limitation to the study and limits the potential to apply quantitative models that include many variables. This issue is especially relevant for index construction, because it specifically requires no missing data values. In order to overcome this challenge, two strategies have been used. Data for missing values has been imputed using the Amelia package in R programming environment. Then categories for different aspects of innovation policy and processes have been merged into composite indexes to reduce the complexity of the model.

The construction of indexes is discussed in greater detail in the following section, this section deals with the first step, imputation. The following assumptions have been used to impute the missing values:

- data are multivariate normal, where a complete dataset has normal distribution, implying that imputed observations are calculated so as to reflect the distribution normality
- data are missing at random, which means that the missingness pattern depends on the observed data rather than the unobserved data

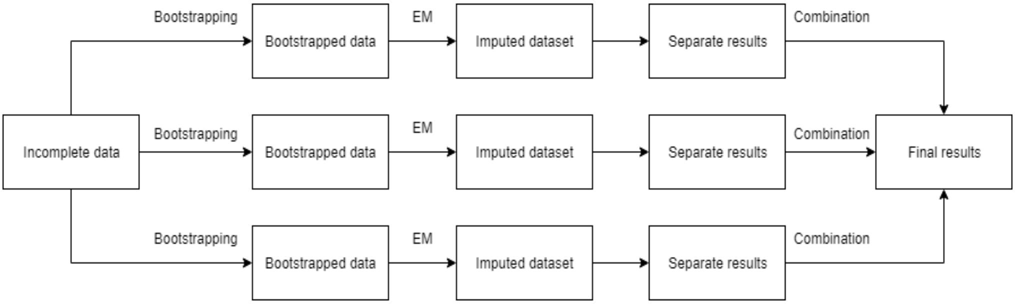
The Amelia package in R uses the expectation-maximization (EM) algorithm with an addition of bootstrapping. The EM algorithm is based on two steps:

- expectation, where the missing value is calculated based on other variable data for the same cross-sectional unit and time period
- maximization, where the likelihood of a value is assessed, and, if the

likelihood is too low, a new round of expectation calculations is run

Meanwhile, the bootstrapping covers the simulation of the uncertainty. Thus, the whole procedure follows the process as outlined in Figure 6 below.

Figure 6. Data imputation process.



Source: Adapted from Honaker, King & Blackwell (2011).

Since there is variation in the imputed values provided by using EM with bootstrapping through the Amelia package for R, the following augmented process was used to fill gaps in the data, in order to maximize the likelihood of imputing the true values for missing data:

- Simple variables were separated into different datasets depending on which composite index they are used for, these parallel values of indicators are used for computations using the EM algorithm.
- R code was written for the particular dataset, employing the Amelia package and taking into account the panel data structure (i.e. the cross-sectional and longitudinal dimensions of the data) and allowing each country unit to have a unique pattern of values' variation over the covered time period.
- Logical limits were put on minimum and maximum values for possible variables (e.g. no negative GDP, variables in percentage values are bounded between 0 and 1, etc.).
- Ten imputations were made for each dataset, for each value a mean was calculated and used as the final values; although ten imputations per dataset might seem to be few, it is important to have in mind that the Amelia EM algorithm already uses bootstrapping, and the maximization part of the EM algorithm allows reiteration. Therefore, the actual number of computations carried out is higher. Only the algorithm itself is run ten times.

3.2. Exploratory analysis of links between electoral systems, innovation, and economic growth

Chapter 3.2 focuses on the basic analysis of the data. First it looks at the descriptive statistics of the data for the used variables. Second, it looks at the differences in data distributions between the group of countries with proportional electoral systems and the group of countries with majoritarian electoral systems. Finally, the implications of the obtained results for model estimation are discussed.

3.2.1. Exploratory Analysis of the Included Indicators

Before proceeding with the estimation of model, it is necessary to overview the general variation and trends in the variables of interest. This section studies the variables related to research by looking at the data using descriptive statistics methods. The discussion follows the structure of the model. First, the specific variables related to economic growth, labour, and capital are assessed. Then, the simple variables used to construct each index are described. It should be noted here, that the non-transformed values are taken and no imputed values are included, in order to reflect the actual situation. Further, in Chapter 3.3, the taken values are z-transformed and log-transformed, where necessary, according to the procedure described in Section 3.1.3. It is not so in this section, in order to make interpretation of the descriptive statistics more intuitive and clearer.

Economic growth, capital, and labour

Table 12 below presents the summary statistics for variables measuring GDP level, growth, capital, and labour. As can be seen, there are large differences between the mean and the median for three indicators (GDP growth is an exception), where median and mean are close. The differences indicate that the sample is skewed despite a relatively high number of observations. Nonetheless, the indicators are corrected by adding a natural logarithm transformation is made to GDP in current PPP, labour force, and gross fixed capital formation indicators. The number of missing observations per indicator is relatively low.

Table 12. Summary statistics for growth, capital and labour indicators

Variable	***Mean***	***Median***	***Minimum***	***Maximum***	***Standard deviation***	***Missing obs.***
GDP PPP	$1.049*10^6$	$2.767*10^5$	8323.8	$1.735*10^7$	$2.66*10^6$	7
Labour force	13895	4660.2	160.06	$1.572*10^5$	29166	7
GFCF	$2.239*10^5$	60917	1708	$3.433*10^6$	$5.525*10^5$	22

Innovation output

Summary statistics for data on innovation output indicators is presented in Table 13. The differences between mean and median values are large for all indicators except for H-Index, publications per researcher, and citations per publications where the values are closer. This suggests that the data are not distributed normally. However, since the indicators are standardised (mean set to 1 and standard deviation set to 0) before being used for index calculations, the problem is addressed. The number of missing observations per variable is relatively small.

Table 13. Summary statistics for innovation output indicators

Variable	***Mean***	***Median***	***Minimum***	***Maximum***	***Standard deviation***	***Missing obs.***
Number of triadic patent families	1115.4	116.19	0.265	17377	3027.5	33
Number of publications	46400	14928	104	$6.267*10^5$	98946	7
Publications per researcher	3.4840	3.0332	0.0026	16.892	1.6525	50
Total number of citations	$8.563*10^5$	$2.138*10^5$	7	$1.399*10^7$	$2.123*10^7$	7
Citations per publication	18.464	17.248	1.3981	46.126	10.160	7
H-Index	531.51	439	114	1783	353.57	7

Knowledge creation (government)

Government knowledge creation indicators differ in their distributions. In general, the variables with non-absolute values (i.e. percentages) give relatively close mean and median values. Thus, the distribution depends on the way that a concept is measured. Nonetheless, all data are standardised (mean set to 1 and standard deviation set to 0) before using it to calculate composite indicator, making the variables comparable and usable for index development. One of the variables, basic research has percentage of GERD, has a high number of missing values. However, imputation of missing value is carried out (see Section 3.1.3 for discussion), before using the variable for composite index construction.

Table 14. Summary statistics for government knowledge creation indicators

Variable	*Mean*	*Median*	*Minimum*	*Maximum*	*Standard deviation*	*Missing obs.*
Gross expenditure on R&D PPP	23755	4569.5	81.375	$4.57*10^5$	70171	38
GERD as % of GDP	1.71	1.622	0.364	3.914	0.848	38
Basic research as % of GERD	0.301	0.272	0.057	0.902	0.141	185
GERD per capita	626.99	595.94	20.878	1697.1	417.1	38
Government funded GERD %	0.573	0.537	0.12	1.157	0.211	74
GBAORD in PPP	8650	1712	25.104	$1.643*10^5$	25528	26

Knowledge creation (private)

Summary statistics for private knowledge creation are provided in Table 15 below. Here, again, the largest differences in data distribution are in terms of non-percentage variable of business expenditure on R&D in PPP, while in other cases mean and median values are close to each other. The transformation to standardise values with mean equalling 0 and standard deviation equalling 1 was carried out, and imputations for missing values have been done. This is especially relevant for indicators share of GERD financed by industry and share of BERD financed by BES, where the numbers of missing observations are relatively high.

Table 15. Summary statistics for knowledge creation (private) indicators

Variable	*Mean*	*Median*	*Minimum*	*Maximum*	*Standard deviation*	*Missing obs.*
% of GERD financed by industry	48.947	47.176	16.51	90.684	12.257	74
Business expenditure on R&D PPP	15791	2466.2	18.314	$3.225*10^5$	49039	38
BERD as % of GDP	1.054	0.933	0.113	3.032	0.67	38
BERD financed by BES	80.182	81.626	30.041	97.478	9.755	79

Knowledge absorption

Summary statistics for knowledge absorption indicators (see Table 16 below) are also comparable to those the discussed above. The difference between mean and median values is large for absolute but not for relative measures. The number of missing observations is not very high, and standardisation and imputation procedures are used to transform data to be useful for constructing the composite indicator for knowledge absorption.

Table 16. Summary statistics for knowledge absorption indicators

Variable	***Mean***	***Median***	***Minimum***	***Maximum***	***Standard deviation***	***Missing obs.***
Total number of researchers full-time equivalent	$1.011*10^5$	31676	1645.6	$1.308*10^6$	$2.262*10^5$	50
Researchers per thousand labour force	6.91	6.649	1.725	15.928	2.998	50
Researchers per thousand employment	7.386	7.026	1.771	17.678	3.189	50
Population with tertiary education	23.970	24.700	5.6294	54.200	9.6221	0
Population with population attending no more than secondary education	29.435	26.524	10.030	83.542	13.216	0

Technology transfer

Technology transfer indicators rely on absolute measures, because more intense flows of knowledge bring more knowledge irrespective of what their relative positions are in the economy. Therefore, as shown in Table 17, the mean and median values differ across all indicators quite significantly. The usual transformations are applied – standardisation (setting mean to 0 and standard deviation to 1) and imputations, which is especially relevant for the R&D expenditure of foreign affiliates variable.

Table 17. Summary statistics for technology transfer indicators

Variable	***Mean***	***Median***	***Minimum***	***Maximum***	***Standard deviation***	***Missing obs.***
R&D expenditure of foreign affiliates PPP	5782.2	1702.6	40.527	52984	10441	239
Technology balance of payments in PPP	9861.9	3664.7	3.014	89415	15368	48
FDI inflows	29960	7747.6	-36602	$4.132*10^5$	58475	77
FDI outflows	36952	8340	-33819	$3.935*10^5$	68851	77
Import	$1.739*10^6$	32977	6.6872	$5.819*10^7$	$6.977*10^6$	15
Export	$1.064*10^6$	53614	4.4584	$2.460*10^7$	$3.546*10^6$	15

3.2.2. Median Comparisons of Indicators Based on Electoral Systems

After discussing the general data structure in Section 3.2.1, Section 3.2.2 turns to comparing the differences in variables between countries with proportional and countries with majoritarian electoral systems. The aim here is to study, whether statistically significant differences between the groups of countries exist in terms of the indicators used in the study. The section is structured similarly to Section 3.2.1. In addition, the differences between country groups in constructed indexes are explored.

As discussed in Section 3.2.1, the untransformed data are not normally distributed. Therefore, instead of a standard unpaired t-test to test statistical significance for groups, we use Mann-Whitney U (MWU) test for unpaired samples (Black, 2009). This test does not require a normal distribution of data within or between samples and, therefore, it suits the present situation. MWU test provides two types of information:

- W (Wilcoxon test) statistic, which is the sum of ranks in one of the tested groups.
- P-value. The null hypothesis states that there is no difference between the two groups. The alternative hypothesis states that the two groups are non-identical.

The MWU test assess if the randomly taken observation from one group has a 50% likelihood of being higher than a randomly taken observation from another group. Since the test, contrary to t-test, does not compare means, in further discussion data on median values of both country-groups is also provided. Median is preferred over mean due to the non-normality in the distribution of the data. However, a not of caution is necessary. MWU test needs independent data, so repeated measurements may also distort the test, because data is treated as pooled instead of panel. This is an important limitation and may affect the results.[22]

Economic growth, capital, and labour

The MWU test for GDP in current PP and labour force size variables clearly shows the difference between countries with majoritarian and countries with

---

[22] Not pooling the data makes the sample size very small, especially due to unequal size of country groups. It was tested on cross-sectional data for the year 2014, only measures in absolute values remain different at a statistically significant level.

proportional electoral systems. The p-values for indicators are very low, and the difference in median values is also high.

Table 18. Country group comparison for growth, capital and labour indicators

Variable	***Majoritarian***	***Proportional***	***W***	***p-value***
GDP PPP	2252045.8	247678.3	15134	<0.001
Labour force	30865.000	4293.476	15023	<0.001
Gross fixed capital formation	360319.54	54794.38	14262	<0.001

Note: numbers for Majoritarian and Proportional are group median values.

Innovation output

The differences between countries with Majoritarian and countries with Proportional electoral systems are clear in terms of innovation output indicators, as indicated by the very low p-values of MWU test (see Table 19). The median values for the variables show better performance of countries with majoritarian electoral systems in nearly all cases, except publications per researcher. This may be affected by the country size (i.e. countries with Majoritarian electoral systems have larger populations / economies; see summary statistics in Section 3.2.1). On the other hand, citations per publication indicate a higher quality of output in majoritarian countries. However, using, the absolute measures are important for the actual increases in output are more likely to bring benefits to a country.

Table 19. Country group comparison for innovation output indicators

Variable	***Majoritarian***	***Proportional***	***W***	***p-value***
Number of triadic patent families	1942.696	71.434	12791	<0.001
Number of publications	145334	13026	15402	<0.001
Publications per researcher	3.108	3.004	8259	0.6637
Total number of citations	2982372	186193	15363	<0.001
Citations per publication	22.319	16.425	9628	0.0204
H-Index	1099	387	15660	<0.001
Innovation output index	0.667	-0.158	14370	<0.001

Note: numbers for Majoritarian and Proportional are group median values.

Knowledge creation (government)

For government knowledge creation, the variables involve both absolute and relative measures (see Table 20). This allows both to capture the general scope of policy and the relative attention given to it, facilitating cross-country comparison. In both cases data distributions between the two country-groups are found to be non-identical. In all cases, the median values for variables are larger for countries with majoritarian electoral systems.

Table 20. Country group comparison for government knowledge creation indicators

Variable	Majoritarian	Proportional	W	p-value
Gross expenditure on R&D PPP	37594.169	3496.857	13645	<0.001
GERD as % of GDP	1.887	1.527	9803	<0.001
Basic research as % of GERD	0.455	0.268	2693	0.03
GERD per capita	731.424	543.889	9510	<0.001
Government funded GERD %	0.613	0.515	8033	0.004
GBAORD in PPP	13507.883	1462.857	13974	<0.001
Knowledge creation (government) index	0.207	-0.153	12969	<0.001

Note: numbers for Majoritarian and Proportional are group median values.

Knowledge creation (private)

For private knowledge creation, most of the variables have non-identical means as indicated by the low p-values of the MWU test (see Table 21). The only exception is the BERD financed by BES variable, where the null hypothesis that the two distributions are identical, cannot be falsified. Therefore, no difference here is expected, as the median values for both groups are also relatively close.

Table 21. Country group comparison for knowledge creation (private) indicators

Variable	Majoritarian	Proportional	W	p-value
% of GERD financed by industry	49.077	47.072	7443	0.056
Business expenditure on R&D PPP	23043.762	1840.581	13663	<0.001
BERD as % of GDP	1.108	0.827	9681	<0.001
BERD financed by BES	82.719	81.328	5964	0.68
Knowledge creation (private) index	0.144	-0.119	11436	<0.001

Note: numbers for Majoritarian and Proportional are group median values.

Knowledge absorption

All knowledge absorption indicators show statistically significant difference in the data distributions in countries with majoritarian and countries with proportional electoral systems. The median values are larger for countries with Majoritarian electoral systems, both for variables measuring absolute values, and for variables measuring relative values.

Table 22. Country group comparison for knowledge absorption indicators

Variable	Majoritarian	Proportional	W	p-value
Total number of researchers full-time equivalent	251931.7	26362	12948	<0.001
Researchers per thousand labour force	7.888	6.156	9280	<0.001
Researchers per thousand employment	8.479	6.713	9224	<0.001
Population with tertiary education	40.00	24.00	2723	<0.001
Population with population attending no more than secondary education	13.58	27.44	14406	<0.001
Knowledge absorption index	0.314	-0.120	11968	<0.001

Note: numbers for Majoritarian and Proportional are group median values.

Technology transfer

All technology transfer indicators have non-identical distributions as shown by MWU test results (see

Table *23*). The median values indicate better performance by the countries with majoritarian electoral systems. Here, variables have absolute values, since the scope of available knowledge is directly related to the absolute rather than relevant indicators. This, of course, relates to country size, but more available knowledge is more likely to affect innovativeness.

Table 23. Country group comparison for technology transfer indicators

Variable	Majoritarian	Proportional	W	p-value
R&D expenditure of foreign affiliates PPP	9204.717	1162.866	4987	<0.001
Technology balance of payments in PPP	16810.917	3239.586	9672	<0.001
FDI inflows	66795.5	6059.2	10037	<0.001
FDI outflows	79235.669	6266.613	10102	<0.001
Imports	$2.126*10^6$	23138	14750	<0.001
Exports	$1.328*10^6$	31751	14541	<0.001
Technology transfer index	0.654	-0.157	14885	<0.001

Note: numbers for Majoritarian and Proportional are group median values.

3.2.3. Implications of the Exploratory Analysis

The summary statistics and country group comparisons have the following implications, relevant for model estimation:

- The data are not distributed normally and depending on the variable, the mean and median variables may differ strongly. This means that data must be transformed before it can be used for further quantitative analysis or specific tests for non-normally distributed data implemented instead of the more standard ones (e.g. MWU test in Section 3.2.2).

- Several variables (e.g. basic research as the percentage of GERD or R&D expenditure of foreign affiliates in current PPP) have a significant number of missing observations. Therefore, in order to preserve the information and not to lose the overall number of observations for regression models, imputation is needed.
- Comparing the data distribution across variables, Mann-Whitney U test shows that for nearly all variables, there are statistically significant differences between countries with majoritarian and countries with proportional electoral systems. This is especially evident for variables measuring the absolute values of constructs, which could at least partially be attributed to the size of countries. However, the relative measures also mostly indicate that the data distributions for countries with Majoritarian and countries with Proportional electoral systems differ, and the median variables are higher for the former group of the countries.
- The two groups of countries also differ in terms of data distribution in terms of composite indicators. The median values for countries with majoritarian electoral systems are higher than for countries with proportional electoral systems.
- The differences in data distributions and the median values of variables for the two groups of countries indicate that:
    - The two groups of countries differ in terms of the used indicators and these differences are statistically significant. Therefore, there are good grounds to expect that the main estimations of the model will provide important insights into the effects of electoral systems on innovation policy and that the relationships will be statistically significant.
    - Countries with Majoritarian electoral systems have higher innovation indicators. This leads to initial expectations that these countries will show stronger innovation policy with respect to indicators reflecting innovation results. However, this does not presuppose that such governments elected under majoritarian rules will implement a more effective policy.

The following chapter presents the main empirical assessment of the proposed theoretical model and hypotheses raised.

3.3. Assessment of Empirical Relationships between Electoral Systems, Innovation, and Economic Growth

After constructing indexes, finalising data cleaning, and implementing the initial analysis of the data, panel data analysis was carried out to estimate the relationships between variables as postulated in the previous chapters of the thesis and to assess the hypotheses raised in Chapter 2.3. The analysis was carried out using open source *gretl* software. The process was as follows:

- After data transformation and index computation was implemented as described in Section 3.2.3, data were merged into a single dataset to facilitate the analysis.
- A specific model was estimated several times with slight modifications:
    - Each model was estimated using pooled OLS, random effects, and weighted least squares methods in all cases. Fixed effects and first differences estimations were implemented, in cases where no time-invariant variables have been included.
    - Models were assessed in terms of lags in order to establish whether the effects depend on time passage. The relevance of different order lags was assessed based on goodness of fit tests. The obtained results vary only little between models, indicating the need for a first order lag to be included. Therefore, only one model (in terms of lags) is presented for each estimation in the main text.
    - In cases of heteroskedasticity and autocorrelation, HAC standard errors have been used. First order lag of dependent variables in equations with economic output and change in economic output was also used, but it did not solve the autocorrelation problem and had nearly no effect on the direction and statistical significance of other relationships. Therefore, only models with HAC standard errors but without lagged dependent variable are presented.

The remainder of Chapter 3.3 is structured along the following lines. Section 3.3.1 presents the panel data analysis results. Since several models with differing dependent and independent variables have been estimated, relevant hypotheses are outlined before providing results, in order to put the model in context. Section 3.3.2 assesses the implications of the obtained results for the hypotheses raised in

Chapter 2.3. Finally, Section 3.3.3 provides the discussion of the implications of the results for the theoretical model and the link between electoral systems, innovation policy, and economic growth.

3.3.1. Estimating Relationships between Electoral Systems, Innovation, and Economic Growth

Dependent variable: GDP (natural log) and GDP per unit of labour force (natural log)

Relevant hypotheses:

- H1. Determinants of economic growth:
  - H1.1. Increase in innovation output has a positive effect on economic growth.
  - H1.2. Increase in knowledge absorption has a positive effect on economic growth.
  - H1.3. Increase in technology transfer has a positive effect on economic growth.

In order to determine the suitable panel data analysis method for the model with total GDP in levels, the following tests have been implemented: joint significance of differing group means, Breusch-Pagan, and Hausman. Results indicated that fixed effects methods is the most suitable for the given data (for results of each test see Appendix 2). However, there is heteroskedasticity (for results of White's test see Appendix 3) and autocorrelation (for results of Durbin-Watson test see Appendix 6), meaning that additional actions must be taken. One approach, which helps to overcome both of these problems, is using heteroskedasticity and autocorrelation consistent (HAC) standard errors, based on Newey-West approach (Newey & West, 1986). Therefore fixed effects model with heteroskedasticity and autocorrelation consistent (HAC) standard errors is used as the main model for testing the hypotheses. Table 24 below shows the results of the analysis for the fixed effects model without the results of time dummy variables (they are provided in Table 1 in Appendix 9). Tables 1 to 3 in Appendix 7 provide estimates obtained from the other three methods for checking if the results across different models are sensitive to estimator choice.

The model suffers from collinearity for two indicators – gross fixed capital formation and active labour force (see Appendix 5), since the log of the total value was used (not in per capita terms, which is addressed in later calculations). To overcome this challenge, estimations have been carried out with capital and labour indicators separately. The log of the size of the active labour force separately was not statistically significantly related to log GDP and did not improve the model; therefore, only capital indicator was kept in the final model, which is discussed below.[23] The independent variables are lagged for one year (first order lag). The choice was made after analysing different length lags, and chosen based on best fit (goodness of fit measures log likelihood and Akaike information criterion indicated better bit with shorter lag).

Finally, time dummies have been added. Two fixed effects models have been estimated, one with time dummies and one without. The comparison of these models' log likelihood and Akaike criterion, shows that a model with time dummies has better fit. Therefore, it is used for the analysis.

Table 24. Dependent variable: log GDP, fixed effects estimation

Independent variable / statistic	Coefficient	Std. Error	t-ratio	p-value
Constant	7.81405	0.512748	15.24	<0.0001
Gross fixed capital formation (log, lag=1)	0.452018	0.0453538	9.966	<0.0001
Innovation output (lag=1)	0.113412	0.0317327	3.574	0.0015
Technology transfer (lag=1)	0.0924333	0.0305999	3.021	0.0057
Knowledge absorption (lag=1)	0.0573173	0.0323023	1.774	0.0882
Within R^2				0.965997
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Note: for convenience, results of time dummy variables are provided in Appendix 9, Table 1.

The results suggest that gross capital formation has a positive effect on the GDP level. Due to multicollinearity between this variable and active labour force, the latter was removed from the model, as it was found not to improve the model if included instead of capital. The effect of gross fixed capital formation is as expected and agrees with the Solow-Swann model, where capital and labour are among the factors of production (cf. Solow, 1956; Jones, 1998), as discussed in Chapter 1.2. The results are little sensitive to the estimation method, as the signs of the coefficients for

[23] Additionally, models were constructed with a lagged dependent variable, but it neither fully solved the autocorrelation problem, nor significantly change or improve the model. Therefore, HAC standard errors were kept.

these indicators remain the same across for three other estimated models (pooled OLS, random effects, and WLS, see Appendix 7).

The effects of the three innovation-related variables are also as expected. The innovation output and technology transfer indexes are positively related to the log of total GDP output at $p < 0.01$ level. The relationship between the technology transfer index and the dependent variable is insensitive to estimation method. The positive effect of innovation output index is also found in the random effects model. Finally, the knowledge absorption index has statistically significant positive relationship with log of total GDP at $p < 0.1$ level. Such effect is also found in random effects and WLS models. This finding agrees with literature that innovation is related to growth, as postulated in the neoclassical (cf. Solow, 1956, Mankiw et al., 1992), neoclassical (cf. Romer, 1990), and evolutionary (cf. Nelson & Winter, 1982) theories of economic growth. The results also support Isaksson (2007) classification, where knowledge creation, technology transfer, and knowledge absorption play an important role as drivers of higher productivity.

In order to assess the effects of innovation on the growth of total GDP rather than the size of the economy, additional analysis of change is carried out below. That is, it is assessed, how the change in total GDP is affected by change in the included independent variables. First differences estimation is also carried out to test if the results are comparable to those obtained from the fixed effects model in levels. The inclusion of the first differences of time dummy provides little direct interpretation, therefore, they are dropped from the model. Other variables are time-variant, and therefore, they are all differenced. Pooled OLS method is used for estimation. Table 25 provides the results.

Table 25. Dependent variable: log GDP, first differences estimation

Independent variable / statistic	Coefficient	Std. Error	t-ratio	p-value
Constant	0.0521246	0.00279783	18.63	<0.0001
GFCF (log, first difference, lag=1)	0.210603	0.0236906	8.890	<0.0001
Innovation output (first difference, lag=1)	0.0554056	0.0145513	3.808	0.0002
Technology transfer (first difference, lag=1)	0.0358499	0.0177182	2.023	0.0439
Knowledge absorption (first difference, lag=1)	−0.00701556	0.0191614	−0.3661	0.7145
Adjusted R^2				0.226879
P-value(F)				<0.0001
Number of obs.	331 (26 cross-sectional units, with time series length between 7 and 13)			

Taking the first differences in the variables (indicating the effect of annual change in independent variables on the annual change in the dependent variable) we can see that change capital positively affects GDP growth in the next time period. The other effects are also similar to those identified in the model in levels with the exception of knowledge absorption (see Table 24). Change in the innovation output index is positively related to change in log total GDP at $p < 0.01$ level, while change in the technology transfer index has positive coefficient at $p < 0.05$ level. Meanwhile, the effect of change in the knowledge absorption index is statistically insignificant. All in all, both fixed effects and first differences estimations provide comparable results, providing supportive evidence on the role of capital, innovation output, and technology transfer on GDP. These results agree with the main theories of economic growth (cf. Jones, 1998; Nelson & Winter, 1982) and lend support to a classification of the determinants of productivity provided by Isaksson (2007), which was used as a bases for defining the innovation channels.

The total GDP and its change capture not only intensive, but also extensive economic growth. To account for this drawback, the model with GDP per unit of active labour force was also estimated. Due to this recalculation of the GDP variable, the indicator for active labour force was not considered for inclusion in the model. Gross fixed capital formation was also recalculated in terms of per unit of active labour force to reflect the calculation of GDP. Panel data analysis method for this model was selected by performing joint significance of differing group means, Breusch-Pagan, and Hausman tests. Results indicated that fixed effects methods is the most suitable for the given data (for results of each test see Appendix 2). However, the data suffers from heteroskedasticity, as indicated by White's test (see Appendix 3), and autocorrelation, as shown by Durbin-Watson test (see Appendix 6). Therefore, fixed effects model with HAC standard errors is used for the analysis, as this method addresses both heteroskedasticity and autocorrelation problems. Table 26 below shows the results of the analysis for the estimated fixed effects model. Tables 4 to 6 in Appendix 7 provide estimates obtained from the other three methods (pooled OLS, random effects, and WLS) for checking the sensitivity of results. No collinearity was identified in the model.

Table 26. Dependent variable: log GDP per unit of ALF, fixed effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	3.41769	0.334767	10.21	<0.0001
GFCF per unit of ALF (log, lag=1)	0.360274	0.120500	2.990	0.0062
Innovation output (lag=1)	0.113135	0.0565252	2.001	0.0563
Technology transfer (lag=1)	0.0827672	0.0376792	2.197	0.0375
Knowledge absorption (lag=1)	0.0897837	0.0317294	2.830	0.0091
Within R^2				0.922135
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Note: for convenience, results of time dummy variables are provided in Appendix 9, Table 2.

The results show that gross fixed capital formation per active labour force has positive and statistically significant effect on GDP per active labour force. This result agrees with the economic growth theories discussed in Chapter 1.2, for example the insights of Solow (1956) or their further development by Mankiw et al. (1992). It is also insensitive to estimation methods, because other estimated models provide estimate statistical significant positive coefficients (see Appendix 7).

The effects of innovation-related variables agree with the theoretical model outlined in Chapter 2.1. They are all positively linked to GDP per active labour force. In the case of technology transfer and knowledge absorption indexes, the results are not sensitive to estimation method; all created models provided statistically significant coefficients similar in the direction of effect. The innovation output index has statistically significant effect in the random effects model, at $p < 0.1$ and in the WLS model at $p < 0.01$ level.

As in the case, of total country's GDP, the analysis of effects of change in innovation indexes on economic growth per unit of active labour force is carried out below. This is done using first differences estimation, in order to test if the results are comparable to those obtained from the fixed effects model. The inclusion of first differences of time dummies does not provide an easy direct interpretation, therefore, they are dropped. Other variables are time-variant, and all are differenced. The pooled OLS method can be used for estimation. Table 27 below provides the results.

Table 27. Dependent variable: log GDP per unit of ALF, pooled OLS estimation

Independent variable / statistic	Coefficient	Std. Error	t-ratio	p-value
Constant	0.0521252	0.00251537	20.72	<0.0001
GFCF per unit of ALF (log, first difference, lag=1)	0.161586	0.0258312	6.255	<0.0001
Innovation output (first difference, lag=1)	0.0518718	0.0144459	3.591	0.0004
Technology transfer (first difference, lag=1)	0.0386077	0.0175791	2.196	0.0288
Knowledge absorption (first difference, lag=1)	−0.00763402	0.0189826	−0.4022	0.6878
Adjusted R^2				0.143703
P-value(F)				<0.0001
Number of obs.	331 (26 cross-sectional units, with time series length between 7 and 13)			

Taking the first differences in the variables (indicating the effect of annual change in independent variables on the annual change in the dependent variable) we can see that change in gross fixed capital formation per unit of active labour force is positively associated with change in GDP per unit of active labour force. Such result could be expected from the economic theory (cf. Jones, 1998) and agree with the results obtained in the model in levels.

The model also finds that change in the innovation output and technology transfer indexes is positively associated with change in economic growth in per capita terms, as could be expected based on Isaksson (2007). This agrees with the theory outlined in Chapter 2.1. Meanwhile, change in knowledge absorption index has no statistically significant effect on change in economic output per unit of active labour force, different to the model in levels provided in Table 26.

The identified relationships generally support the idea that innovation policy affects economic growth positively. This helps to address the first part of the raised research problem, by providing evidence of positive effect across the different innovation channels.

Dependent variable: innovation output index

Relevant hypotheses:

- H2. Determinants of innovation output:
    - H2.1. Knowledge absorption has a positive effect on innovation output.
    - H2.2. Government knowledge creation has a positive effect on innovation output.

- H2.3. Private knowledge creation has a positive effect on innovation output.
- H2.4. Technology transfer has a positive effect on innovation output.
- H2.5. Government knowledge creation has a larger positive effect on innovation output when the country has a proportional electoral system than when it has a majoritarian electoral system.
- H2.6. Knowledge absorption has a larger positive effect on innovation output when the country has a proportional electoral system than in the case of a majoritarian electoral system.
- H2.7. Technology transfer has a larger positive effect on innovation output when the country has a proportional electoral system than in the case of a majoritarian electoral system.
- H2.8. Proportional electoral systems have a larger positive effect on innovation output in comparison to the majoritarian electoral systems.

In order to determine the suitable panel data analysis method for the model with innovation output joint significance of differing group means and Breusch-Pagan tests have been implemented. Hausman test was not used, because the model includes a time-invariant variable, and fixed effects model would not be feasible. The results indicate that random effects method is more suitable for the given data (for results of each test see Appendix 2). There is heteroskedasticity in the model (see Appendix 3). The autocorrelation is on the boundary of being problematic (i.e. Durbin-Watson statistics is slightly below 1.5). These two problems suggest the need for using HAC standard error. Table 28 below shows the results of the random effects model, while Tables 7 and 8 in Appendix 7 provide estimates obtained from pooled OLS and fixed effects models for checking if the results across different models vary (i.e. the sensitivity of results). The fixed effects estimation is not used due to there being time-invariant variable, which cannot be dropped because of its importance in the theoretical framework and for the hypotheses testing (electoral system).

The model suffers from collinearity among several indicators (see Appendix 5). This is so because the model uses first order interaction variables. Therefore, it is certain that certain values of indicators move together, and they are highly related.

However, due to the structure of the model, it is a common practice to use interaction variables in such way, and not including the non-interacted forms would provide less suitable results (Allen, 2004). All variables used in interaction terms can have a natural value of zero. Therefore, they are not additionally centred.

Table 28. Dependent variable: innovation output index, random effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*z*	*p-value*
Constant	0.485472	0.159938	3.035	0.0024
Knowledge absorption (lag=1)	0.274067	0.112099	2.445	0.0145
Government knowledge creation (lag=1)	0.163578	0.0397683	4.113	<0.0001
Private knowledge creation (lag=1)	0.0553032	0.0588833	0.9392	0.3476
Technology transfer (lag=1)	0.0750370	0.0324626	2.311	0.0208
Electoral system (proportional=1)	−0.541365	0.176501	−3.067	0.0022
*Proportional system * Knowledge absorption (lag=1)*	−0.455049	0.149399	−3.046	0.0023
*Proportional system * Government knowledge creation (lag=1)*	0.260548	0.141476	1.842	0.0655
*Proportional system * Technology transfer (lag=1)*	0.228545	0.0941862	2.427	0.0152
Between variation				0.0995844
Within variation				0.020184
Mean theta				0.878978
Number of obs.	371 (27 cross-sectional units, with time series length between 8 and 14)			

Several conclusions can be drawn from the model. First, the findings suggest that the effect of proportional electoral systems on innovation output index is negative. This finding is stable across all three methods of estimation (random effects, pooled OLS, and weighted least squares). Therefore, the findings suggest that proportional electoral systems do not lead to higher innovation performance in the country.

The private knowledge creation index does not have direct effect on innovation output index, which is a an unexpected finding, as it could be expected that private investment should lead to better innovation outcomes. On the other hand, all variables linked to policy are determinants of innovation output, as they are positively associated with the innovation output index at $p < 0.05$ level. These three coefficients are in agreement with what the model suggested.

Finally, the theoretical model provided in Chapter 2.1 also postulated the moderating effect of electoral systems. This is accounted by the interaction variables in the model. The random effects model shows several interesting insights. All the moderating relationships are statistically significant. They show that the effect of government knowledge creation and technology transfer have more positive effect on innovation output under proportional electoral systems rather than under majoritarian ones. This is in line with the argument that governments elected under proportional representation rules are more likely to be subject to higher accountability (Persson & Tabellini, 2008; Knutsen, 2011; Knutsen & Rasmussen, 2018), and therefore, implement policies more effectively and efficiently. At the same time, due to the geographic dimension of innovation activities (Rallet & Torre, 2017), governments elected through such electoral rules should be less inclined to use innovation policy as a tool for re-election. This is supported by the findings of the discussed model.

However, knowledge absorption has stronger positive effect under majoritarian electoral rules, as shown by the negative coefficient of the respective interaction variable.

Alternative estimations provided in Appendix 7 (Tables 7 and 8) show that results are sensitive to estimation method, thus, the results might be treated with greater caution. The least sensitive result concerns the effect of electoral system and the effect of the interaction between electoral system and government knowledge creation index (similar across all three models) The first difference estimation is not implemented, because electoral systems variable is time-invariant, and therefore, it would always have a value of zero across all units and time periods, rendering the model meaningless.

The general findings of this model suggest that electoral systems indeed affect how innovation policy channels affect innovation output and economic growth through it. The innovation policy brings higher benefits if it is implemented in countries with proportional electoral systems, with the exception of knowledge absorption. Thus, the model addresses the research problem by providing the evidence that electoral systems affect the effect of innovation channels on innovation outputs and, consequently, growth.

The effect of electoral systems on individual innovation indexes

The effect of electoral systems on individual innovation indexes has also been estimated. The findings suggest that proportional electoral system negatively affects knowledge absorption. The finding is robust across two estimation methods, the exception is random effects. In terms of government creation, the proportional electoral system also has negative effect, which is robust across different estimation methods. A similar finding concerns technology transfer index. It is lower under governments elected via proportional representation rules. The finding is robust across different estimation methods.

Relevant hypotheses:

- H3. Effects of electoral systems on the separate innovation channels:
    - H3.1. The majoritarian electoral systems have a larger positive effect on knowledge absorption in comparison to the proportional electoral systems.
    - H3.2. The majoritarian electoral systems have a larger positive effect on technology transfer in comparison to the proportional electoral systems.
    - H3.3. The majoritarian electoral systems have a larger positive effect on government knowledge creation in comparison to the proportional electoral systems.

In order to determine the suitable panel data analysis method of the effect of electoral systems on the knowledge absorption, technology transfer, and government knowledge creation indexes, joint significance of differing group means and Breusch-Pagan tests have been implemented.[24] Test results indicated that random method is the most suitable for the given data (for results of each test see Appendix 2). There is also heteroskedasticity, including groupwise heteroskedasticity (for results of White's and Wald's tests see Appendix 3). This suggests the need for using robust standard error, and also groupwise WLS methods, to help overcome these challenges. WLS with HAC standard errors can also account for the autocorrelation problem in the data, and, therefore, is the chosen method for the analysis. Table 29, Table 30, and Table 31 below show the results of the analysis.

Tables 9 to 14 in Appendix 7 provide estimates obtained from pooled OLS and WLS methods for checking if the results across different models vary or are insensitive to the estimation method. Fixed effects estimation is not implemented due to there being time-invariant variable, which cannot be dropped because of its

[24] The Hausman test was not used, since only a time-invariant independent variable and time dummies were included in the model, thus, it would not be possible to use fixed effects estimation for the main variable of interest electoral systems.

importance in the theoretical framework and for the hypotheses testing (electoral system).

Table 29. Dependent variable: knowledge absorption index, random effects estimation

Independent variable / statistic	Coefficient	Std. Error	z	p-value
Constant	0.459087	0.0333949	13.75	<0.0001
Electoral system (proportional=1)	−0.387695	0.107711	−3.599	0.0003
Between R^2				0. 247911
Within R^2				0.0182951
Mean theta				0.929191
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Note: for convenience, results of time dummy variables are provided in Appendix 9, Table 3.

Table 30. Dependent variable: technology transfer index, random effects estimation

Independent variable / statistic	Coefficient	Std. Error	z	p-value
Constant	0.567563	0.237569	2.389	0.0169
Electoral system (proportional=1)	−0.847205	0.247932	−3.417	0.0006
Between R^2				0.13139
Within R^2				0.0221364
Mean theta				0.893357
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Note: for convenience, results of time dummy variables are provided in Appendix 9, Table 4.

Table 31. Dependent variable: government knowledge creation index, random effects estimation

Independent variable / statistic	Coefficient	Std. Error	z	p-value
Constant	0.226835	0.270121	0.8398	0.4010
Electoral system (proportional=1)	−0.611469	0.285467	−2.142	0.0322
Between R^2				0.194871
Within R^2				0.00878044
Mean theta				0.944617
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Note: for convenience, results of time dummy variables are provided in Appendix 9, Table 5.

The link between electoral systems and used innovation indexes suggests that proportional electoral system leads to lower innovation intensity. This means lower public contribution to innovation development (as theorised in the previous chapters), lower absorption capacities, and less intense technology transfer processes. These findings agree with Kim (2011), who finds that majoritarian electoral rules are associated with higher public expenditure on R&D. This also suggests that innovation policy is more closely related to the regionally bounded public goods as opposed to social transfers (cf. Milesi-Ferretti et al., 2002), with implications for the economic geography of innovation (cf. Ferru & Rallet, 2016; Rallet & Torre, 2017).

However, while these results support the developed theoretical framework, some caution should be taken in interpreting the results. Since, in this case, only a time-invariant dummy variable is used, and it does not form a part of interaction indicators with other variables, the longitudinal dimension inflates the number of observations, but does not necessarily provide additional robustness to results.

In terms of the research problem, this set of models helps to evaluate the impact of electoral systems on the intensity of innovation policy. While the previous analysis showed that in terms of government knowledge creation and technology transfer proportional representation electoral systems can lead to more effective/efficient policy, these findings show that the scope of policy would, however, be smaller. This, again, provides insights into the research problem addressed in this dissertation.

3.3.2. Results of the Assessment of Hypotheses

The empirical analysis allows assessing hypotheses raised in Part 2 of the dissertation. The following rules of thumb are used:

- Models in first differences help to assess how change in an independent variable affects change in the dependent variable, while also making data stationary. Therefore, where possible (i.e. no time-invariant variables included), models in differences are used for primary assessment, while results from other models serve as additional tests of the strength of the relationships between variables.
- In order to assess if the estimated relationships' coefficients are statistically significant, the threshold of $p < 0.1$ value is used, which can be considered acceptable in applied econometrics Gujarati, 2004).
- Accepting of rejecting a hypothesis is primarily based on fixed effects and first differences estimations for models without time-invariant variables. For models with time-invariant variables, random effects models are used. However, the discussion of the robustness of the conclusion comes from the

other estimated models (pooled OLS, random effects, WLS). This helps to identify the relative sensitivity of the obtained result, given that different methods help to deal with different challenges (e.g. groupwise WLS diminishes groupwise heteroskedasticity).

- A hypothesis is considered supported, if the main used model agrees shows a statistically significant effect of the independent variable in the expected direction.
- When references to main models are used in Table 32 below, they refer to the models, which are used for hypotheses assessment: fixed effects for (H1.1-H1.3) and random effects for (H2.1-H2.8 and H3.1-H3.3). Supporting models are other (non-preferred) estimations of the relationships between the selected dependent and independent variables, their results are provided in Appendix 7.

Table 32. Assessment of hypotheses

Hypothesis	**Assessment and arguments**
H1.1. Increase in innovation output has a positive effect on economic growth.	**Supported.** The hypothesis is supported, as the effect of increase in innovation output on economic growth is positive in the fixed effects models is statistically significant at $p < 0.01$ and $p < 0.05$ levels. In the models in differences, the relationship is positive and statistically significant at $p < 0.01$ level in both cases as well. Therefore, there is a strong agreement between the models that innovation output leads to a higher economic output, even if other estimations do not always find the positive relationship.
H1.2. Increase in knowledge absorption has a positive effect on economic growth.	**Rejected.** Only fixed effects models in levels show that knowledge absorption has a positive and statistically significant effect on the level of GDP. Two models in first differences find no statistically significant link at $p < 0.1$ level, thus suggesting that the hypothesis should be rejected, even if supportive models provide more optimistic results.
H1.3. Increase in technology transfer has a positive effect on economic growth.	**Supported.** The hypothesis is supported, because technology transfer index has a positive effect on GDP in both models in levels (statistically significant at $p < 0.01$ level). The relationship also holds for the model in differences at $p < 0.05$ level. Additional estimations also show a stable positive and statistically significant relationship between technology transfer and economic growth. Therefore, the evidence for the support of the hypothesis is strong.

H2.1. Knowledge absorption has a positive effect on innovation output.	**Rejected.** The evidence on the relationship between knowledge absorption and innovation output is ambiguous. Although the coefficient is positive and statistically significant at $p < 0.05$ level, the interaction term must also be taken into effect. The individual coefficient is 0.274067, while the interaction coefficient is −0.455049 (statistically significant at $p < 0.01$ level). The sum of these coefficients equals −0.180982. This indicates that the effect of knowledge absorption is positive in the countries with the majoritarian electoral systems, but negative in the countries with the proportional electoral systems, and there is no specific effect direction that would hold constant. Therefore, the hypothesis is rejected.
H2.2. Government knowledge creation has a positive effect on innovation output.	**Supported.** The model shows that the government knowledge creation index is positively related to the innovation output index, as evidenced by the positive coefficient of the individual indicator (statistically significant at $p < 0.01$) and the positive coefficient of its interaction with the electoral system indicator (statistically significant at $p < 0.1$ level). Since both coefficients are positive, the evidence support the hypothesis. However, the results of the supporting models are more ambiguous, so the hypothesis should be treated with some caution.
H2.3. Private knowledge creation has a positive effect on innovation output.	**Rejected.** No statistically significant direct relationship between the private knowledge creation index and the innovation output index has been identified in the model. Therefore, there is no reason to accept the hypothesis, even if additional models show positive relationship.
H2.4. Technology transfer has a positive effect on innovation output.	**Supported.** The model shows that the technology transfer index is positively related to the innovation output index, as evidenced by the positive coefficient of the individual indicator and the positive coefficient of its interaction with the electoral system indicator (both statistically significant at $p < 0.05$ level). Since both coefficients are positive, the evidence support the hypothesis. The results of the additional models are ambiguous, so hypothesis should be treated with some caution.
H2.5. Government knowledge creation has a larger positive effect on innovation output when the country has a proportional electoral system than when it has a majoritarian electoral system.	**Supported.** The model identified a positive effect of both the government knowledge creation index and its interaction term with the electoral systems as statistically significant at $p < 0.01$ and $p < 0.1$ levels respectively. It shows that, when a country uses a proportional electoral system, the effect of the government knowledge creation index on innovation output is higher (0.424126) than when a country uses the majoritarian electoral rules (0.163578). This finding supports the hypothesis, further confirmed by the supporting models.

H2.6. Knowledge absorption has a larger positive effect on innovation output when the country has a proportional electoral system than in the case of a majoritarian electoral system.	**Rejected.** The knowledge absorption index has a positive effect on the innovation output index, when the country has a majoritarian electoral system (the coefficient is 0.274067 and statistically significant at $p < 0.05$ level). It is higher than in the countries with the proportional electoral systems (the sum of the individual and interaction coefficients is −0.180982 and statistically significant at $p < 0.05$ level). Therefore, the hypothesis is rejected, as the effect of the proportional electoral system is opposite to the expected one. Additional models find no statistically significant relationship.
H2.7. Technology transfer has a larger positive effect on innovation output when the country has a proportional electoral system than in the case of a majoritarian electoral system.	**Supported.** The technology transfer index has a positive effect on the innovation output index irrespective of the electoral system that a country has adopted. However, the effect is higher in the countries with the proportional electoral systems (the sum of individual and interaction coefficients equals 0.303582) in comparison with the countries with the majoritarian electoral systems (0.0750370). The results are statistically significant at $p < 0.05$ level. Therefore, the hypothesis is supported, even if the results are sensitive to the estimation method.
H2.8. Proportional electoral systems have a larger positive effect on innovation output in comparison to the majoritarian electoral systems.	**Rejected.** The direct relationship between the electoral system and the innovation output index was found to be negative and statistically significant at $p < 0.01$ level, contrary to the expectations. Therefore, the hypothesis is rejected. Additional models identified the coefficients with the negative sign at a statistically significant level as well.
H3.1. The majoritarian electoral systems have a larger positive effect on knowledge absorption in comparison to the proportional electoral systems.	**Supported.** The proportional electoral systems are found to be negatively linked to knowledge absorption (statistically significant at $p < 0.01$ level) in the random effects model. Therefore, the hypothesis is supported. Additional models also find a statistically significant effect in a similar direction.
H3.2. The majoritarian electoral systems have a larger positive effect on technology transfer in comparison to the proportional electoral systems.	**Supported.** The proportional electoral systems are found to be negatively linked to technology transfer (statistically significant at $p < 0.01$ level) in the random effects model. Therefore, the hypothesis is supported.
H3.3. The majoritarian electoral systems have a larger positive effect on government knowledge creation in comparison to the	**Supported.** The proportional electoral systems are found to be negatively linked to government knowledge creation (statistically significant at $p < 0.05$) level in the random effects model. Therefore, the hypothesis is supported.

proportional electoral systems.	

The results and their implications for hypotheses that have been discussed in this chapter so far, allow assessing the theoretical model outlined in the Chapter 2.1 of the dissertation. This section discusses them, based on the assessment of hypotheses presented in Table 32. The discussion begins with the impact of electoral systems on innovation indexes, then goes onwards toward the analysis of the impact of innovation indexes on innovation output, and finally, on their effects on economic growth.

3.3.3. Implications of Results and Contribution to Existing Research

Direct effects of electoral systems on innovation indexes

The models assessing the relationship between electoral systems and the three innovation indexes (government-led knowledge creation, knowledge absorption, and technology transfer) show that in general, the intensity of innovation channels is higher in countries with majoritarian electoral systems than in countries with proportional electoral systems, as predicted in the theoretical framework developed in Chapter 2.1. It also suggests that innovation policy is more of a regionally bounded public good rather than social transfer, which helps locate this policy area in the framework by (Milesi-Ferretti et al., 2002) and frame it in the context of more recent literature on the spatial dimension of economic and social policies in the context of electoral institutions (Jurado & Leon, 2017). It also further supports the suggestion of the geographical clustering of innovation activities (Rallet & Torre, 2017), effectively connecting the two frameworks. The analysis of geographic concentration of innovation policy in the government failure, could help provide a new perspective to the analysis of the geography of innovation, which needs certain renewal (Ferru & Rallet, 2016), for example, in the form of new dimensions (e.g. government failure). It also contributes to the literature on regional innovation paradox (Oughton et al., 2002; Muscio et al., 2015), suggesting that political institutions can further aggravate the absorption of public innovation funding.

Looking more specifically at the separate indexes, first, it is clear that governments elected under majoritarian rules see investment in R&D as a means to directly affect constituencies important for re-election. To put it in another way, governments treat support for knowledge creation as regionally bounded public good spending in terms of Milesi-Ferretti et al. (2002) framework. The results are consistent with those obtained by Kim (2011), and correlate with findings by Batinti & Congleton (2018) that voters can take into account R&D policy, even if they concentrate particularly on health area.

The knowledge absorption is higher in countries with majoritarian electoral systems than in countries with proportional electoral systems. It was considered a broader policy category than government-led knowledge creation spending, since it is partly affected by the education policy, which could be also considered closer to transfer spending than regionally bounded public good.[25] However, the findings show that knowledge absorption tends to be higher in countries with majoritarian electoral systems. This finding may possibly be related to several factors:

- countries with majoritarian electoral systems invest more actively in education and ensure its provision, and education institutions tend to be concentrated at higher levels of education, affecting the geography of human capital, which can spillover to innovation activities (e.g. emergence of innovative startup firms (Calcagnini, G., Favaretto, I., Giombini, G., Perugini, F., & Rombaldoni, R. (2016))
- the number of researchers and their share in the labour force are important for knowledge creation, therefore, governments may encourage their training or hiring in specific locations (related to R&D investment, as discussed above)
- spending on R&D (a part of the government-led knowledge creation index) is a targeted regionally bounded public good, and since more researchers work where R&D activities are more intense, governments are interested in ensuring environment friendly to employing them

The technology transfer is also more intense in countries with majoritarian electoral systems than in countries with proportional electoral systems, as expected. In theory, it could be argued that governments elected through proportional electoral systems focus more on diffusion of knowledge, since it can happen across different regions. However, it might well be the case that governments use policy tools to

[25] It can be noted that this variable of all used innovation channels is the most sensitive to changes in the estimation method, suggesting that the identified relationship might be weak. Further analysis is needed, possibly also splitting a single knowledge absorption index into separate indicators.

attract FDI in specific locations or that technology transfer happens to mostly take place in regions, where innovative businesses are more likely to be concentrated, again stressing the role of the geography of innovation. This would mean that majoritarian governments could be interested in more active technology transfer policy. Since technology transfer index is based on absolute values, it is also possible that the effect of country size is important.[26]

To summarise, innovation activities seem to be more intense in countries with majoritarian electoral rules compared to countries with proportional electoral rules. This is in line with the existing research (Kim, 2011), and stresses the role of innovation policy as a geographically-bounded public good, locating it in the broader classification of economic and policy (Milesi-Ferretti et al. 2002). This affects not only government-led knowledge creation, but also knowledge absorption and technology transfer.

Direct effects of innovation indexes on innovation output

As expected, the empirical analysis showed that government knowledge creation and technology transfer have positive effect on innovation output. This is in line with the body of literature studying innovation (Azoulay, Graff Zivin & Sampat, 2018; Borensztein et al., 1998; Minniti & Venturini, 2017). However, contrary to expectations the private knowledge creation index did not identify a statistically significant effect on innovation output. This may be surprising, given the dominant strands in literature (Guellec & De La Potterie, 2003), but can be explained by the following:

- the links between government and private R&D spending can partially mask the effect of private R&D
- due to the nature of the innovation output index, public effects may be easier to identify (e.g. patents result from private and public activities, while publications are more likely to result from public activities)

In any case, this lack of support for the positive relationship between private government creation and innovation output is worth exploring in future research.

[26] Additional calculations to test this assumption were carried out by adding labour force size as a proxy for the effect of country's size. The effect of electoral systems retained its direction and remained statistically significant.

Meanwhile, knowledge absorption provides a mixed effect on innovation output, which depends on the electoral system. It is discussed in greater detail below.

Indirect effects of electoral systems on innovation output through moderation

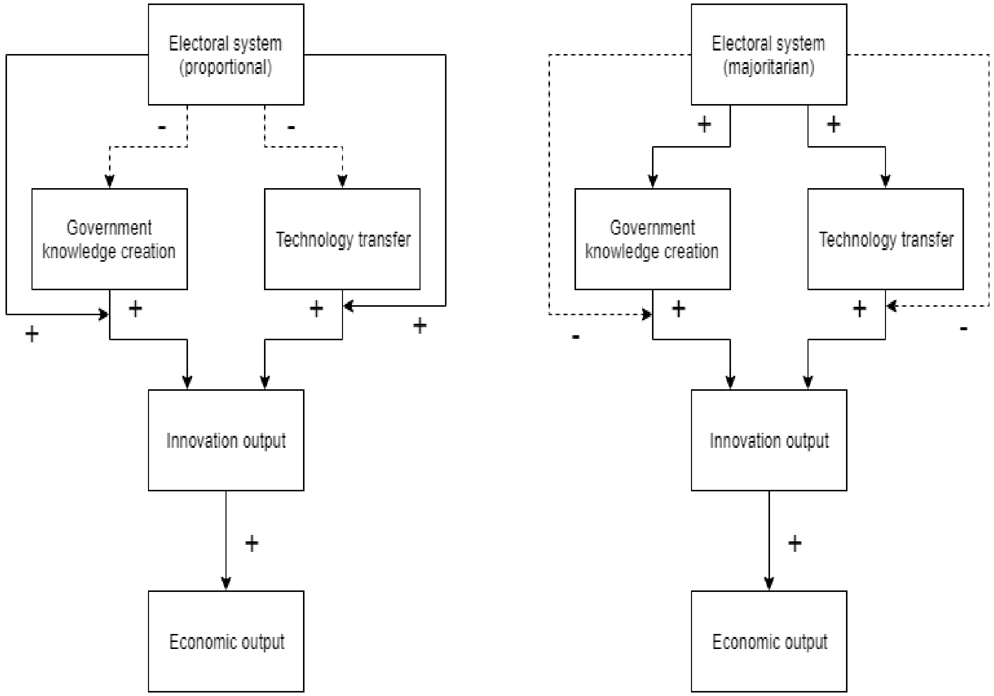
The results show that the effects of all three innovation channels are affected by the electoral rules, which moderate the effects of the government knowledge creation, knowledge absorption, and technology transfer indexes on the innovation output index. This suggests that policy effectiveness differs, based on the way in which a government is selected. This has the following implications for the scientific discussion.

First, the government-led knowledge creation has stronger positive effect on innovation output, when the electoral system in the country is proportional than when the electoral system is majoritarian (see Figure 7). This is in line with the theoretical model – it means that government investment in R&D and similar activities is more effective, when the government is elected under proportional electoral rules. The proposed explanation is that innovation policy can affect electoral outcomes if it performs well, when a country uses proportional electoral rules. Meanwhile, majoritarian rules give incentives for a government to spend more, but without much care of economic effectiveness of such spending. The impact on the prospects of re-election is more important. This finding and interpretation is in line with the argument that proportional electoral systems encourage higher accountability and incentivise governments to perform better (Persson & Tabellini, 2008; Knutsen, 2011; Knutsen & Rasmussen, 2018). Therefore, the empirical analysis provides support to the implication of the theoretical model that (parts of) innovation policy may be more intense in countries with majoritarian electoral rules, but more effective in countries with proportional electoral rules. Effective innovation policy is likely to affect a broader but more dispersed group of people, while targeted investment with less focus on the actual outcomes, might be more effective in affecting specific locations.

A similar finding concerns technology transfer (see Figure 7), where the positive effect on innovation output is stronger for countries with proportional electoral systems, suggesting that at least in terms of innovation, trade and FDI policy is more effective, when the government is elected under proportional rules. This adds to the ongoing discussion on the relationship between electoral systems and trade policy (Rickard, 2015), and complement research finding positive association between majoritarian electoral rules and FDI (Garland & Biglaiser, 2009) in terms of intensity.

A new angle, however, is the effectiveness of such policy in terms of technology transfer. The results suggest that proportional systems are performing better, hereby, adding to the existing scientific literature.

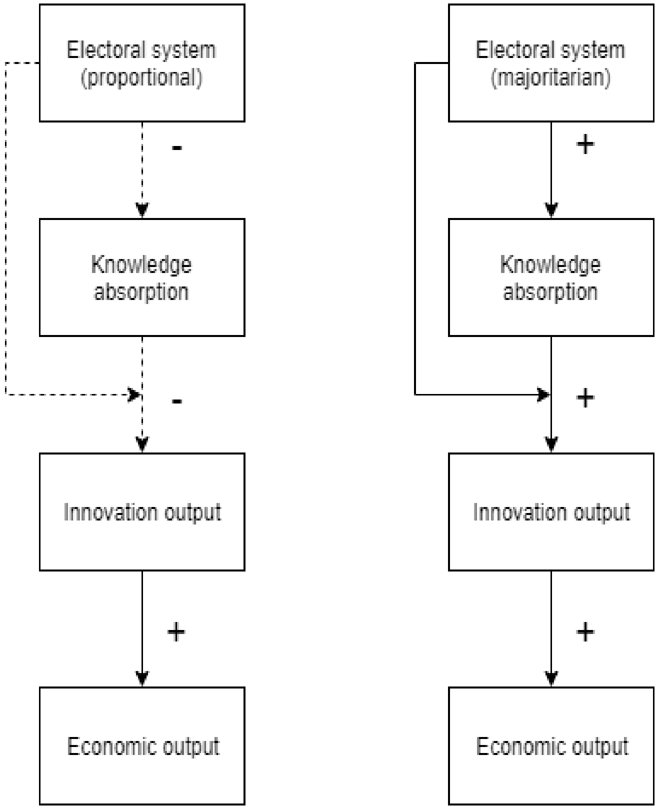
Figure 7. Moderation effects of electoral systems on government knowledge creation and technology transfer.



Note: signs indicate relationship between variables. Dashed lines indicate negative relationship, full lines indicate positive relationship. Signs of effects of electoral systems are relative to the other system.

The most contradictory finding is related to the interaction between proportional electoral systems and knowledge absorption index (see Figure 8). Here, the effect on innovation output is positive, when a country has majoritarian electoral rules, but negative, when the rules are proportional. This is a surprising finding and not expected, given the theoretical model, and could be interesting for further consideration in future research.

Figure 8. Effects of electoral systems on knowledge absorption



Note: signs indicate relationship between variables. Dashed lines indicate negative relationship, full lines indicate positive relationship. Signs of effects of electoral systems are relative to the other system.

The evidence show that electoral systems are important not only in how intense policy is, but also – how effective. There is little research on it, and what exists, is contradictory, due to variety of reasons (Rickard, 2017). The area of innovation has hitherto received little attention, therefore, the findings add both to the general understanding of how government behaviour depends on its selection mechanism and to new advances in the innovation studies, where there has been little attention given to specific political institutions.

Direct effects of innovation indexes on economic growth

The analysis of the effect of innovation indexes on economic growth showed that, in line with standard economic theory, capital positively affects both the economic output level and its change is positively related to economic growth rate.

Such result is in line with the main economic theories, starting with Solow-Swan model of economic growth (Solow, 1956), its later adaptations (Mankiw et al. 1992), and other theories of economic growth (Jones, 1995). Similarly, the effect of innovation output on economic output in levels, and the effect of change in innovation output on economic growth is as predicted by the theoretical model and also corresponds to the body of economic growth research on innovation as one of the main drivers of productivity.

Of the other innovation indexes, technology transfer has positive effect on the level of economic output and its change is positively related to the economic growth rate. This is proposed in the theoretical framework. Certainly, the technology transfer indicator captures more than just availability and adoption of technology. Therefore, its indirect impact through innovation output is more interesting in terms of the current study (discussed above). Nonetheless, the finding suggests that availability of technology through foreign economic relations, positively affects economic performance. Meanwhile, knowledge absorption levels are positively related to GDP levels, but change in knowledge absorption is not related to change in GDP at a statistically significant level. Therefore, the relationship is dubious, and further investigation is needed, focusing specifically on this link, which was not the object of this research.

Indirect effects of electoral systems on economic output and growth via innovation (moderation)

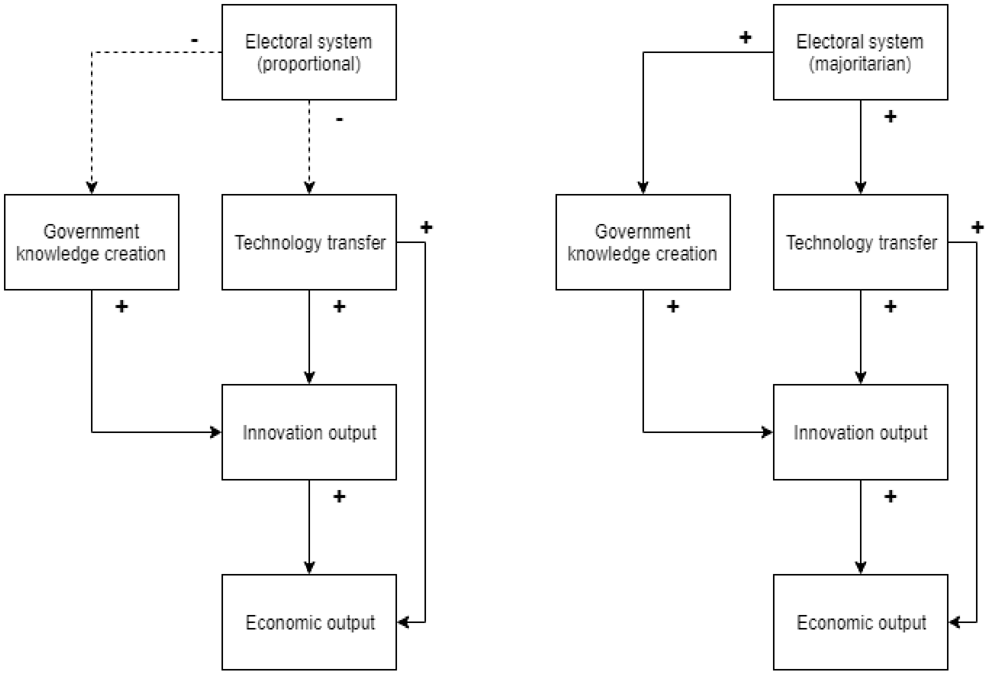
The effects of electoral systems via innovation indexes are several, and to an extent (but not fully) in line with the proposed theoretical framework (see Figure 9):

- majoritarian electoral systems are related to economic output and economic growth through the following channels:
    - a positive effect (relative to proportional electoral systems) on the level government knowledge creation, which has a positive effect on innovation output, thus, positively affecting economic performance
    - positive effect on technology transfer (relative to proportional electoral systems), which has a positive effect on innovation output, and consequently, positive effect of economic performance; technology transfer also has direct positive effect on economic output
    - however, the positive effect of both these channels (government

knowledge creation and technology transfer) is weaker in countries with majoritarian electoral systems (see discussion on moderation above), meaning that these policies are less impactful, at least in terms of economic performance

- proportional electoral system is positively related to economic output and economic growth through the following channels:
    - a negative effect on government knowledge (relative to majoritarian electoral systems), thus reducing its intensity, which has positive effect on innovation output and economic performance, through this channel
    - a negative effect on technology transfer (relative to majoritarian electoral systems), which positively affects innovation output and economic performance
    - however, the positive effect of both these channels (government knowledge creation and technology transfer) is stronger in countries with proportional electoral systems (see discussion on moderation above), meaning that these policies are more impactful at least in terms of economic performance

Figure 9. Indirect effects of electoral systems on innovation indexes mediated through innovation channels.



Note: signs indicate relationship between variables. Dashed lines indicate negative relationship, full lines indicate positive relationship. Signs of effects of electoral systems are relative to the other system. No moderation effects are indicated, as they are outlined in Figure 7 and Figure 8, knowledge transfer is not included due to its ambiguous effect, discussed above.

The basic implications of the theoretical model were that: first, the electoral systems affect innovation policy; second, the majoritarian electoral systems lead to a more intense policy; third, the proportional electoral systems lead to more effective innovation policy. To an extent all these implications of the theoretical model are supported by the data. First, the electoral systems are related to innovation. Second, greater intensity of innovation policy in countries with majoritarian electoral systems has been confirmed not only for government-led knowledge creation but also for knowledge absorption and technology transfer. Third, the effectiveness of innovation policy insofar as captured by the government-led knowledge creation and technology transfer, is higher in countries with proportional electoral systems (though not for knowledge absorption). Although not all hypotheses have been supported by the data analysis, the essence of the theoretical model is supported, suggesting that further research on the interaction between constitutional institutions and innovation policy could be fruitful and lead to new policy implications.

CONCLUSIONS AND RECOMMENDATIONS

1. The analysis and synthesis of the scientific literature allowed to define the prevailing view on the interaction between innovation policy and economic growth in the following way:

- The conception of innovation policy has developed from the narrow, i.e. based on the linear model of innovation, to a broad one, covering research on innovation systems, and to the holistic one, which encompasses all the governmental actions that may affect innovation. It reflects the deepening understanding of the interaction of a large variety of factors' potential to affect the innovation activities and their outcomes in a given innovation system.
- The innovation activities are subject to market and system failures. Initially, the given research focused on market failure and its solutions (e.g. R&D subsidies, IPR protection) rather than the systemic aspects. Later on it has been discovered that the interactions between the agents are no less important. It led to a partial re-focus of innovation and innovation policy studies on system failure, thus broadening the scope of the instruments of innovation policy by embracing other policy areas (e.g. education, trade etc.).
- The innovation activities operate as an important driver of the economic growth in the discussed major theories of the economic growth (i.e. neoclassical, endogenous and evolutionary) allowing to overcome the steady state of growth and enabling change in the technological frontier, which increases the productivity of capital and labour.

2. The analysis of the scientific literature helped to conceptualise the expected impact of the electoral institutions on innovation policy and its interrelation with growth. From this the following conclusions can be made:

- The issue of government failure has attracted little consideration (and, mostly, from the theoretical perspective) in the analysed literature on innovation policy. However, it can be viewed as a potentially significant determinant of the intensity of the innovation policy as well as its effectiveness and efficiency. One of the factors creating government failure is institutional setting, i.e. the defining rules how the government agents are elected and how they act.

- Government spending depends on the electoral systems. They provide incentives for the government agents to act in certain ways so as to maximise their chances of election. Therefore, the electoral systems have an impact on policy orientation either toward the regionally bounded public goods (primarily affecting the individuals in the specific geographic locations) or toward social transfer payments (primarily affecting the specific social groups of individuals across countries).
- The innovation policy may be considered as focusing more on the provision of regionally bounded public goods than on social transfers due to the geographic concentration of economic activities. Therefore, the more intense innovation policy should be implemented in the countries with the majoritarian electoral systems than in the countries with the proportional electoral systems. Nevertheless, since, generally, the innovation policy is not expected to significantly affect the re-election chances of a government elected through the proportional representation rules, such policy might have a stronger impact on the economic development, because it is not focused on the improving chances for getting re-elected.

3. On the basis of the analysis of the scientific literature, a specific theoretical model defining the interaction of electoral institutions, innovation policy and economic growth has been constructed. It has led to the following conclusions:

- There is a large variety of factors affecting the economic growth, but innovation and technology development have been seen among the main drivers of productivity since the early theorising on the process of the economic growth.
- Three broad channels through which the innovation activities may affect the economic growth have been distinguished. 1) knowledge creation (funded by the government or the private sector) affects the innovation output by directly creating new knowledge, which can be used for further innovation activities. 2) technology transfer, often spilling over from the foreign economic agents, which may provide access to knowledge previously unavailable in the domestic economy, thus encouraging the adoption of new technologies and their use in other innovation activities. 3) knowledge absorption, which enables the economic agents to utilise available knowledge in their activities, including innovation activities. These three innovation channels affect the

innovation output, which, in its turn, affects the economic growth.

- The electoral systems may exert the following two effects on the economic growth through innovation policy. First, it can indirectly affect the economic growth through government knowledge creation, technology transfer and knowledge absorption. The proposed model suggests that the majoritarian electoral rules are associated with higher investment in knowledge creation and better outcomes of technology transfer and knowledge absorption. Second, the electoral systems can mediate the impact of these innovation channels on the innovation output and, consequently, the economic growth. The model implies that this latter type of impact are positive and stronger reflected in the countries with the proportional electoral systems.

4. The comparative analysis of the empirical methods allowed to work out an econometric model in approaching the given research problem:

- There are several types of models, which can be employed for the analysis of the impact of the innovation policy on the economic growth. The main approach traditionally selected in the cross-country research is that of growth regressions based on the multivariate regression analysis where the economic output and its alteration are used as the dependent variable. Another approach is related with the use of the general equilibrium models, which require more detailed specification of the economic processes in a country, possibly incorporating innovation policy. Finally, emerging approaches, such as agent based modelling or neural network modelling can be employed to investigate the relationship between the economic growth and its determinants.
- All methods have their advantages and drawbacks. Considering the research object, the growth regressions approach is preferable due to several reasons. Firstly, it allows for incorporating many countries over a time period. It should be noted that this is more difficult to implement with the use of general equilibrium models or agent based modelling. Secondly, this approach works with the macro-level data, which is relevant for this research. Other methods would work better with the less aggregated data, except the neural networks approach. Thirdly, the growth regressions approach allows for testing theory and analysing the specific relationships among variables, which would not be possible by using the neural network

modelling. Fourthly, growth regressions allow for incorporating different variables drawn from the theories found in innovation research, which would be more difficult in the majority of other discussed approaches.

- Based on the developed theoretical model, the three groups of hypotheses have been developed. The first group covers the determinants of the economic output and its changes. The model implies the positive effect of innovation output, technology transfer, knowledge absorption, capital, and labour indicators. The second group of hypotheses discusses the determinants of the innovation output (i.e. government and private knowledge creation, technology transfer and technology absorption with expectation of their positive interaction) and the effect of the electoral systems, where the proportional electoral systems were postulated to positively affect the innovation output and increase the positive effect of the innovation channels in contrast to the majoritarian electoral systems. The third group of hypotheses covers the direct impact of the electoral systems on the innovation channels. In line with the developed theoretical model, they suggested that the impact will be positive in the countries with the majoritarian electoral systems compared to the countries with the proportional electoral systems.
- The system of econometric equations was developed to include all the hypotheses. It consists of five equations, in which innovation output, government knowledge creation, technology transfer and knowledge absorption in some equations are dependent variables but independent in others. This enables the capturing of the indirect effects of electoral systems on the interrelation between innovation policy and economic growth.

5. The empirical research based on the proposed model had the following attributes and offers the following main implications for the theoretical model:

- The developed methodology for the empirical research contained several steps. First, the dataset was analysed for the missing values, and imputation procedures were run to fill them in. Second, the composite indicators based on the factor analysis were constructed for innovation output, government and private knowledge creation, technology transfer and knowledge absorption. Third, the exploratory analysis based on descriptive statistics and Mann-Whitney U test was implemented to better understand the structure of the indicators and the differences between two groups of countries divided by their electoral systems.

- The developed methodology was used to test the hypotheses with the data from the OECD countries over the period of 2000–2014. The inclusion of the OECD countries only helped to create a more homogeneous sample, possibly removing the effect of the development factors, which could affect the analysed relationships, as evidenced in the scientific literature on innovation policy and economic growth.
- The analysis used the fixed effects and first differences estimation methods, when no time-invariant variables were used, and random effects estimation, when time-invariant variables were included. In total, eight models have been estimated in testing the hypotheses, with the additional pooled OLS, WLS and random effects estimations to assess the sensitivity of the results.
- The values of three innovation channels, i.e. government knowledge creation, technology transfer and knowledge absorption, are higher in the countries with the majoritarian electoral systems. This finding confirms the related hypotheses and shows that the governments elected under the majoritarian electoral systems implement a more active innovation policy (i.e. government knowledge creation) or ensure higher outcome related activities (i.e. knowledge absorption and technology transfer). It suggests that innovation policy is closer to regionally bounded public good than social transfer, because the results imply that geography is an important determinant of such policy.
- Government knowledge creation and technology transfer have a positive effect on the innovation output. The impact of both of these variables is stronger in the countries with the proportional electoral systems, thus suggesting that the policy implemented in such countries is better targeted at ensuring economic rather than political returns, and well supports the respective hypotheses. On the other hand, the impact of knowledge absorption on the innovation output is positive in the countries with the majoritarian electoral systems but not in the countries with the proportional electoral systems, thus contradicting the implications of the model related to knowledge absorption.
- The direct effect of the proportional electoral systems on the innovation

output is negative, thus indicating that, all the other factors held equal, the innovation output is higher in the countries with the majoritarian electoral systems. It contradicts the hypothesis implied by the theoretical model, but the effect is also countered by a stronger positive effect of government knowledge creation and technology transfer in the countries with the proportional electoral systems.

- Both indirect and moderating effects of electoral systems have been identified. They show that the electoral institutions have an indirect impact on the economic output through the innovation output and innovation channels. At the same time, they moderate the effect of the innovation channels on the innovation output. This quantity vs. quality insight is significant in evaluating the role of electoral incentives for government behaviour in innovation policy.

6. The empirical analysis has the following main implications given research problem in the context of existing research:

- As reflected in literature, research in constitutional economics and public choice has long been interested in the effects of political institutions on economics, and electoral systems have attracted considerable attention (Congleton, 2018; Persson & Tabellini, 2008; Knutsen, 2011; Knutsen & Rasmussen, 2018). The obtained results are in line with the main findings that electoral systems affect government incentives and policy but invite for discussion by assessing the impact on policy effectiveness through specific pathways (i.e. innovation channels), which have not yet been explored to the best knowledge of the author of the thesis.
- Although the research on the effect of the specific political institutions on innovation policy is rather rare, there is an agreement between findings (Kim, 2011) or linking the voters' decision and the R&D policy implementation (Batinti & Congleton, 2018), thus supporting the statement that election prospects play an important role in the implementation of innovation policy. This is also in line with the scientific literature that considers the role of the political systems in the functioning of innovation systems in general (Fagerberg, Lundvall, & Srholec, 2018; Fagerberg & Srholec, 2008).
- The nature of innovation policy related with providing either regionally bounded public goods or social transfers is not always easy to define (Kim, 2011), due to a variety of instruments used. Within the Milesi-Ferretti et al.

(2002) framework, it was shown that innovation policy likely provides more regionally bounded goods than transfers. This relates to the literature in the economic geography of innovation, where the geographic concentration of innovation is stressed (Ferru & Rallet, 2016; Rallet & Torre, 2017), which also adds a new policy dimension. Furthermore, the regional orientation of innovation policy reflects the so called regional innovation paradox (Ougthon et al., 2002; Muscio et al., 2015), thus indicating that difficulties in the absorption of the innovation policy funds can be aggravated by the less suitable political institutions.

The findings of the carried out research also provide the following directions for future investigation:

- If relevant data becomes available, the offered model could be used to analyse the interaction between innovation policy, economic growth and electoral rules in the developing economies. Given the varying levels of policy effectiveness that depends on the country's level of development, such research could provide additional insights into how constitutions shape the economic evolution of the countries that are still undergoing development.
- The impacts of the political institutions other than electoral rules could be included in the model for the analysis of their importance in distinguishing the effects that they may have on the innovation systems. This would require a new model, focusing not only on the electoral incentives of the government agents but also on the limitations imposed by the constitutional rules affecting and limiting governmental behaviour.
- The analysis of a specific policy instrumentarium in terms of scope and effectiveness under different electoral institutions could be used to determine which specific types of policies might be effective under different constitutional settings. Such research would have high practical significance due to comparative/contrastive analysis of the specific innovation channels. For example, the role of R&D tax incentives could be compared against the role of R&D subsidies, while taking into account the effect of different electoral systems.

REFERENCES

1. Acs, Z. J., Estrin, S., Mickiewicz, T., & Szerb, L. (2014). *The continued search for the solow residual: The role of national entrepreneurial ecosystem. IZA Discussion Paper Series, discussion paper No. 8652.* Institute of Labour Economics, Bonn, Germany. Retrieved from http://ftp.iza.org/dp8652.pdf

2. Acs, Z. J., & Sanders, M. W. (2013). Knowledge spillover entrepreneurship in an endogenous growth model. *Small Business Economics*, *41*(4), 775-795.

3. Adams, S. (2009). Intellectual property rights, political risk and economic growth in developing countries. *Journal of Economics and International Finance*, *1*(6), 127-134.

4. Adkins, L. C., Waters, M. S., & Hill, R. C. (2015). *Collinearity diagnostics in gretl.* Paper presented at the 4th Gretl Conference, Berlin. Retrieved from https://learneconometrics.com/pdf/Collin/collin_gretl.pdf

5. Aghion, P. (2012). *From growth theory to growth policy design*. London, UK: Economic & Social Research Council, London School of Economics. Retrieved from http://www.lse.ac.uk/researchandexpertise/units/growthcommission/documents/pdf/aghion_growthdoc_apr2012.pdf

6. Aghion, P., & Durlauf, S. (2009). Growth regressions and policy evaluation. In P. Aghion & S. Durlauf (Eds.), *From growth theory to policy design, working paper No. 57*. World Bank. Retrieved from http://siteresources.worldbank.org/EXTPREMNET/Resources/489960-1338997241035/Growth_Commission_Working_Paper_57_Growth_Theory_Policy_Design.pdf

7. Aghion, P., & Howitt, P. (1992). A Model of Growth Through Creative Destruction. *Econometrica, 60*(2), 323-351.

8. Allen, M. P. (2004). *Understanding regression analysis*. Berlin, Germany: Springer Science & Business Media.

9. Angeles, L. (2011). Institutions, property rights, and economic development in historical perspective. *Kyklos*, *64*(2), 157-177.

10. Armingeon, K., Wenger, V., Wiedemeier, F., Isler, C., Knöpfel, L., Weisstanner, D., & Engler, S. (2019). *Comparative political data set 1960-2017*. Institute of Political Science, University of Bern. Retrieved from http://www.cpds-data.org

11. Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In R. R. Nelson (Ed.), *The rate and direction of inventive activity: Economic and social factors* (pp. 609-626). Princeton, New Jersey, US: Princeton University Press.

12. Azoulay, P., Graff Zivin, J. S., Li, D., & Sampat, B. N. (2018). Public R&D investments and private-sector patenting: Evidence from NIH funding rules. *The Review of Economic Studies*, *86*(1), 117-152.

13. Bach, L., & Matt, M. (2005). From economic foundations to S&T policy tools: A comparative analysis of the dominant paradigms. In P. Llerena & M. Mireille (Eds.), *Innovation policy in a knowledge-based economy* (pp. 17-45). Berlin, Germany: Springer.

14. Batinti, A., & Congleton, R. D. (2018). On the codetermination of tax-financed medical R&D and healthcare expenditures: Models and evidence. *European Journal of Political Economy*, *54*, 175-188.

15. Bayoumi, T., Coe, D. T., & Helpman, E. (1999). R&D spillovers and global growth. *Journal of International Economics*, *47*(2), 399-428.

16. Beinhocker, E. D. (2006). *The origin of wealth: Evolution, complexity, and the radical remaking of economics.* Boston, Massachusetts, US: Harvard Business School Press.

17. Bernanke, B. S., & Gürkaynak, R. S. (2002). Is growth exogenous? Taking Mankiw, Romer, and Wweil seriously. In B. S. Bernanke & K. Rogoff (Eds.), *NBER Macroeconomics Annual 2001* (Vol. 16, pp. 11-72). Cambridge, Massachusetts, US: MIT Press.

18. Black, K. (2009). *Business statistics: Contemporary decision making*. New York, New York, US: John Wiley & Sons.

19. Boero, R. (2015a). Economic impacts of lack of coordination in the governance of public policies. In R. Boero, M. Morini, M. Sonnessa & P. Terna (Eds.), *Agent-based models of the economy: From theories to applications* (pp. 161-183). London, UK: Palgrave Macmillan.

20. Boero, R. (2015b). Ex-ante evaluation of public policies: Unintended

results of broadband development. In R. Boero, M. Morini, M. Sonnessa & P. Terna (Eds.), *Agent-based models of the economy: From theories to applications* (pp. 146-160). London, UK: Palgrave Macmillan.

21. Borensztein, E., De Gregorio, J., & Lee, J. W. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics*, *45*(1), 115-135.

22. Borrás, S., & Edquist, C. (2013). The choice of innovation policy instruments. *Technological Forecasting and Social Change*, *80*(8), 1513-1522.

23. Brautzsch, H. U., Günther, J., Loose, B., Ludwig, U., & Nulsch, N. (2015). Can R&D subsidies counteract the economic crisis?–Macroeconomic effects in Germany. *Research Policy*, *44*(3), 623-633.

24. Bravo-Ortega, C., & Marin, A. G. (2011). R&D and productivity: A two way avenue? *World Development*, *39*(7), 1090-1107.

25. Brecard, D., Fougeyrollas, A., Le Mouel, P., Lemiale, L., & Zagame, P. (2006). Macroeconomic consequences of European research policy: Prospects of the Nemesis model in the year 2030. *Research Policy*, *35*(7), 910-924.

26. Bryant, K. (2001). Promoting innovation: An overview of the application of evolutionary economics and systems approaches to policy issues. In J. Foster & S. Metcalfe (Eds.), *Frontiers of evolutionary economics: Competition, self-organization and innovation policy* (pp. 361-384). Northampton, Massachusetts, US: Edward Elgar Publishing.

27. Bueno de Mesquita, B., Smith, A., Siverson, R. M., & Morrow, J. D. (2003). *The logic of political survival*. Cambridge, Massachusetts, US: MIT Press.

28. Bulman, D., Eden, M., & Nguyen, H. (2017). Transitioning from low-income growth to high-income growth: Is there a middle-income trap? *Journal of the Asia Pacific Economy*, *22*(1), 5-28.

29. Busom, I., Corchuelo, B., & Martínez-Ros, E. (2017). Participation inertia in R&D tax incentive and subsidy programs. *Small Business Economics*, *48*(1), 153-177.

30. Calcagnini, G., Favaretto, I., Giombini, G., Perugini, F., & Rombaldoni, R. (2016). The role of universities in the location of innovative start-ups. *The Journal of Technology Transfer*, *41*(4), 670-693.

31. Castellacci, F., & Lie, C. M. (2015). Do the effects of R&D tax credits vary across industries? A meta-regression analysis. *Research Policy*, *44*(4), 819-832.

32. Cefis, E., & Marsili, O. (2005). A matter of life and death: Innovation and firm survival. *Industrial and Corporate Change*, *14*(6), 1167-1192.

33. Chambers, D., & Guo, J. T. (2007). *Natural resources and economic growth: Theory and evidence.* Berkeley, California, US: University of California, Department of Economics. Retrieved from https://econ.ucr.edu/papers/papers07/07-09.pdf

34. Chaminade, C., Lundvall, B. Å., & Haneef, S. (2018). *Advanced introduction to national innovation systems*. Cheltenham, UK: Edward Elgar Publishing.

35. Chen, D. H. C. & Dahlman, C. J. (2004). Knowledge and Development: A Cross-Section Approach. *Policy Research Working Paper ;No.3366.* World Bank, Washington, D.C. US. Retrieved from: https://openknowledge.worldbank.org/handle/10986/14163

36. Choudhary, M. A., & Haider, A. (2012). Neural network models for inflation forecasting: An appraisal. *Applied Economics*, *44*(20), 2631-2635.

37. Čiegis, R. (2006). *Ekonominių teorijų istorija*. Vilnius, Lithuania: Vilniaus universiteto leidykla.

38. Coase, R. H. (1937). The nature of the firm. *Economica*, *4*(16), 386-405.

39. Coccia, M. (2012). Political economy of R&D to support the modern competitiveness of nations and determinants of economic optimization and inertia. *Technovation*, *32*(6), 370-379.

40. Congleton, R. D. (2018). Intellectual foundations of public choice, the forest from the trees. *Public Choice*, *175*(3-4), 229-244.

41. D'Agostino, G., & Scarlato, M. (2012). *Innovation, socio-institutional conditions and economic growth in the Italian regions*. Internet source. Retrieved from

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2195541

42. D'Agostino, G., & Scarlato, M. (2014). Inclusive institutions, innovation and economic growth: estimates for European countries. Internet source. Retrieved from:

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2539521

43. David, P. A., Hall, B. H., & Toole, A. A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy*, *29*(4-5), 497-529.

44. Dawid, H., Gemkow, S., Harting, P., & Neugart, M. (2012). Labour market integration policies and the convergence of regions: The role of skills and technology diffusion. *Journal of Evolutionary Economics*, *22*(3), 543-562.

45. Di Comite, F., & Kancs, D. A. (2015). *Macro-economic models for R&D and innovation policies-A comparison of QUEST, RHOMOLO, GEM-E3 and NEMESIS*. *IPTS Working Papers on Corporate R&D and Innovation, working paper No. 03/2015.* Joint Research Centre, European Commission. Retrieved from https://pdfs.semanticscholar.org/1d16/f40d9f28cf3098a6906d5b3b076d410d97e7.pdf?_ga=2.26711608.405087082.1567268738-7410411.1567268738

46. Diao, X., Roe, T., & Yeldan, E. (1999). Strategic policies and growth: An applied model of R&D-driven endogenous growth. *Journal of Development Economics*, *60*(2), 343-380.

47. Durlauf, S. N., Johnson, P. A., & Temple, J. R. W. (2005). Growth econometrics. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth*, (Vol. 1A, pp. 555-677). Amsterdam, The Netherlands: Elsevier.

48. Durlauf, S. N., Kourtellos, A., & Tan, C. M. (2008). Are any growth theories robust? *The Economic Journal*, *118*(527), 329-346.

49. Edler, J., & Fagerberg, J. (2017). Innovation policy: What, why, and how. *Oxford Review of Economic Policy*, *33*(1), 2-23.

50. Edler, J., & Georghiou, L. (2007). Public procurement and innovation—Resurrecting the demand side. *Research Policy*, *36*(7), 949-963.

51. Edler, J., Gök, A., Cunningham, P., & Shapira, P. (2016). Introduction: Making sense of innovation policy. In J. Edler, A. Gök, P. Cunningham, & P. Shapira (Eds.), *Handbook of innovation policy impact* (pp. 1-17). Cheltenham, UK: Edward Elgar Publishing.

52. Edquist, C. (2001). *The systems of innovation approach and innovation policy: An account of the state of the art.* Paper presented at the DRUID Conference, Aalborg. Retrieved from http://www.obs.ee/~siim/seminars/edquist2001.pdf

53. Edquist, C. (2011). Design of innovation policy through diagnostic analysis: Identification of systemic problems (or failures). *Industrial and Corporate Change*, *20*(6), 1725–1753.

54. Edquist, C. (2014). Striving towards a Holistic Innovation Policy in European countries – But linearity still prevails! *STI Policy Review, 5*(2), 1-19.

55. Edquist, C., & Hommen, L. (1999). Systems of innovation: Theory and policy for the demand side. *Technology in Society*, *21*(1), 63-79.

56. Eggink, M. E. (2012). Innovation system performance: How to address the measurement of a system's performance. *Journal of Innovation and Business Best Practices*, *2012*, 1-9.

57. Epstein, J. M., & Axtell, R. (1996). *Growing artificial societies: Social science from the bottom up*. Washington, D.C., US: Brookings Institution Press.

58. Etzkowitz, H., & Ranga, M. (2010, October). *A Triple Helix system for knowledge-based regional development: From "spheres" to "spaces".* Paper presented at the Triple Helix Association 8th International Conference, Madrid. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.642.4594&rep=rep1&type=pdf

59. Fagerberg, J. (2015). *Innovation policy, national innovation systems and economic performance: In search of a useful theoretical framework. TIK Working Papers on Innovation Studies, working paper No. 20150321.* University of Oslo. Retrieved from https://www.sv.uio.no/tik/forskning/Forskergrupper/innovasjonsgruppen/InnoWP/tik_working_paper_20150321.pdf

60. Fagerberg, J. (2017). Innovation policy: Rationales, lessons and challenges. *Journal of Economic Surveys*, *31*(2), 497-512.

61. Fagerberg, J., & Fosaas, M. (2014). *Innovation and innovation policy in the Nordic region.* University of Oslo, Center for Technology, Innovation and Culture. Retrieved from https://mpra.ub.uni-muenchen.de/58394/1/MPRA_paper_58394.pdf

62. Fagerberg, J., Lundvall, B. Å., & Srholec, M. (2018). Global value chains, national innovation systems and economic development. *The European Journal of Development Research*, *30*(3), 533-556.

63. Fagerberg, J., & Srholec, M. (2008). National innovation systems, capabilities and economic development. *Research Policy*, *37*(9), 1417-1435.

64. Fagerberg, J., Srholec, M., & Knell, M. (2007). The competitiveness of nations: Why some countries prosper while others fall behind. *World Development*, *35*(10), 1595-1620.

65. Fagerberg, J., & Verspagen, B. (2007). Innovation, growth and economic development: Have the conditions for catch-up changed? *International Journal of Technological Learning, Innovation and Development*, *1*(1), 13-33.

66. Fagerberg, J., & Verspagen, B. (2009). Innovation studies—The emerging structure of a new scientific field. *Research Policy*, *38*(2), 218-233.

67. Falvey, R., Foster, N., & Greenaway, D. (2006). Intellectual property rights and economic growth. *Review of Development Economics*, *10*(4), 700-719.

68. Feldman, M. P., & Kogler, D. F. (2010). Stylized facts in the geography of innovation. In B. H. Hall & N. Rosenberg (Eds.), *Handbook of the economics of innovation* (Vol. 1, pp. 381-410). Amsterdam, The Netherlands: Elsevier.

69. Fernández-Villaverde, J., & Rubio-Ramírez, J. F. (2009). *A baseline DSGE model* (Unpublished manuscript). Retrieved from https://www.sas.upenn.edu/~jesusfv/benchmark_DSGE.pdf

70. Ferru, M., & Rallet, A. (2016). Proximity dynamics and the geography of innovation: Diminishing returns or renewal? In R. Shearmur, C. Carrincazeaux & D. Doloreux (Eds.), *Handbook on the geographies of innovation* (pp. 100-122). Cheltenham, UK: Edward Elgar Publishing.

71. Fike, R., & Gwartney, J. (2015). Public choice, market failure, and government failure in principles textbooks. *The Journal of Economic Education*, *46*(2), 207-218.

72. Flanagan, K., & Uyarra, E. (2016). Four dangers in innovation policy studies–and how to avoid them. *Industry and Innovation*, *23*(2), 177-188.

73. Foss, N. J. (1998). The new growth theory: Some intellectual growth accounting. *Journal of Economic Methodology*, *5*(2), 223-246.

74. Freeman, C. (1995). The ‘National System of Innovation’ in historical perspective. *Cambridge Journal of Economics*, *19*(1), 5-24.

75. Freeman, C., & Soete, L. (2009). Developing science, technology and innovation indicators: What we can learn from the past. *Research Policy*, *38*(4), 583-589.

76. Fusco, E., Vidoli, F., & Sahoo, B. K. (2018). Spatial heterogeneity in composite indicator: A methodological proposal. *Omega, 77,* 1-14

77. Garland, M. W., & Biglaiser, G. (2009). Do electoral rules matter? Political institutions and foreign direct investment in Latin America. *Comparative Political Studies*, *42*(2), 224-251.

78. Garson, G. D. (2014). *Path analysis*. Asheboro, North Carolina, US: Statistical Associates Publishing.

79. Ginarte, J. C., & Park, W. G. (1997). Determinants of patent rights: A cross-national study. *Research Policy*, *26*(3), 283-301.

80. Godin, B. (2006). The Linear model of innovation the historical construction of an analytical framework. *Science, Technology & Human Values*, *31*(6), 639-667.

81. Godin, B. (2014a). The Linear Model of Innovation: The Historical Construction of an Analytical Framework. In A. N. Link & C. Antonelli (Eds.), *Recent developments in the economics of science and innovation*. Cheltenham, UK: Edward Elgar Publishing.

82. Godin, B. (2014b). *The vocabulary of innovation: A lexicon. Project on the Intellectual History of Innovation, working paper No. 20.* L'Institut national de la recherche scientifique, Montreal, Quebec, Canada. Retrieved from http://www.csiic.ca/PDF/LexiconPaperNo20.pdf

83. Gonzalez, S. (2000). *Neural networks for macroeconomic forecasting: A complementary approach to linear regression models*. *Working paper No. 2000-07.* Economic and Fiscal Policy Branch, Department of Finance, Canada. Retrieved from https://pdfs.semanticscholar.org/17cf/e6431e77bb56fba518a4e249ad73658972cb.pdf?_ga=2.19081663.628956695.1567363128-661022779.1565441553

84. Gould, D. M., & Gruben, W. C. (1996). The role of intellectual property rights in economic growth. *Journal of Development Economics*, *48*(2), 323-350.

85. Goulder, L. H., & Schneider, S. H. (1999). Induced technological change and the attractiveness of CO2 abatement policies. *Resource and*

Energy Economics, *21*(3), 211-253.

86. Greenhalgh, C., & Rogers, M. (2010). *Innovation, intellectual property, and economic growth*. New Jersey, US: Princeton University Press.

87. Grossman, G. M., & Helpman, E. (1990). Trade, innovation, and growth. *The American Economic Review*, *80*(2), 86-91.

88. Guellec, D., & De La Potterie, B. V. P. (2003). R&D and productivity growth. *OECD Economic studies*, *2001*(2), 103-126.

89. Gujarati, D. N. (2004). *Basic econometrics*. New Dehli, India: Tata Mc-Graw Hill Publishing Company Limited.

90. Hammami, S. (2013). Intellectual property rights and economic growth: Evidence from a cross-country data of developing countries. *Journal of Economics and Sustainable Development*, *4*(18), 77-84.

91. Happe, K., Balmann, A., Kellermann, K., & Sahrbacher, C. (2008). Does structure matter? The impact of switching the agricultural policy regime on farm structures. *Journal of Economic Behavior & Organization*, *67*(2), 431-444.

92. Hasan, I., & Tucci, C. L. (2010). The innovation–economic growth nexus: Global evidence. *Research Policy*, *39*(10), 1264-1276.

93. Hofer, R., & Polt, W. (1998). Evolutionary innovation theory and innovation policy: An overview. In K. Bryant & A. Wells (Eds.), *A new economic paradigm? Innovation-based evolutionary systems: Discussions of science and innovation 4*. Canberra, Australia: Department of Industry, Science and Resources.

94. Holden, T. (2010). *Products, patents and productivity persistence: A DSGE model of endogenous growth*. *Dynare Working Papers Series, working paper No. 4.* Department of Economics, University of Oxford. Retrieved from https://www.dynare.org/wp-repo/dynarewp004.pdf

95. Hollanders, H., Es-Sadki, N., & Merkelbach, I. (2019). *European Innovation Scoreboard 2019*. European Commission. Retrieved from https://ec.europa.eu/docsroom/documents/36281/attachments/1/translations/en/renditions/native

96. Honaker, J., King, G., & Blackwell, M. (2011). Amelia II: A program for missing data. *Journal of Statistical Software*, *45*(7), 1-47.

97. Hong, C., Yang, H., Hwang, W., & Lee, J. D. (2014). Validation of an

R&D-based computable general equilibrium model. *Economic Modelling*, *42*, 454-463.

98. Hudson, J., & Minea, A. (2013). Innovation, intellectual property rights, and economic development: A unified empirical investigation. *World Development*, *46*(C), 66-78.

99. Huo, J. (2015). *How nations innovate: The political economy of technological innovation in affluent capitalist economies*. Oxford, UK: Oxford University Press.

100. Isaksson, A. (2007). Determinants of total factor productivity: A literature review. *Research and Statistics Branch Staff Working Paper 02/2007*, Research and Statistics Branch, United Nations Industrial Development Organization. Retrieved from https://open.unido.org/api/documents/4812034/download/UNIDO-Publication-2007-4812034

101. Jones, C. (1998). *Introduction to economic growth (2nd ed.)*. New York, New York, US: W. W. Norton & Company.

102. Jones, C. I. (1995). R&D-based models of economic growth. *Journal of Political Economy*, *103*(4), 759-784.

103. Jones, C. I., & Williams, J. C. (1998). Measuring the social return to R&D. *Quarterly Journal of Economics, 113*(4), 1119-1135.

104. Jurado, I., & Leon, S. (2017). Geography matters: The conditional effect of electoral systems on social spending. *British Journal of Political Science*, *49*(1), 1-23.

105. Karo, E. (2011). *Governance of innovation policy in catching-up context: Theoretical considerations and case studies of Central and Eastern European economies*. Tallinn, Estonia: Tallinn University of Technology.

106. Kim, J. (2011). Political institutions and public R&D expenditures in democratic countries. *International Journal of Public Administration*, *34*(13), 843-857.

107. Knutsen, C. H. (2011). Which democracies prosper? Electoral rules, form of government and economic growth. *Electoral Studies*, *30*(1), 83-90.

108. Knutsen, C. H., & Rasmussen, M. B. (2018). Electoral rules, labor market coordination and macroeconomic performance. *Scandinavian Political Studies*, *41*(3), 367-378.

109. Kraujelytė, A., & Petrauskas, R. (2007). Technologijų perdavimo vaidmuo inovacijų procese: Lietuvos inovacijų politikos perspektyva. *Viešoji politika ir administravimas, 19*, 54-68.

110. Kuhlmann, S. (2001). Future governance of innovation policy in Europe—three scenarios. *Research Policy*, *30*(6), 953-976.

111. Kuhlmann, S., & Edler, J. (2003). Scenarios of technology and innovation policies in Europe: Investigating future governance. *Technological Forecasting and Social Change*, *70*(7), 619-637.

112. Lane, D. A. (1992). *Artificial worlds and economics*. *Santa Fe Institute working paper No. 1992-09-048.* Santa Fe Institute. Retrieved from https://pdfs.semanticscholar.org/9ff4/fabc75cbe586d505505b1af80b03a029677f.pdf?_ga=2.197090857.405087082.1567268738-7410411.1567268738

113. Lengnick, M. (2013). Agent-based macroeconomics: A baseline model. *Journal of Economic Behavior & Organization*, *86*, 102-120.

114. Lundvall, B. A. (1992). *National innovation system: Towards a theory of innovation and interactive learning*. London, UK: Pinter.

115. Lundvall, B. Å. (2007). National innovation systems—analytical concept and development tool. *Industry and Innovation*, *14*(1), 95-119.

116. Lundvall, B. A., & Borrás, S. (2005). Science, technology, innovation and knowledge policy. In J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 599-631). Norfolk, UK: Oxford University Press.

117. Malerba, F., Nelson, R., Orsenigo, L., & Winter, S. (2008). Vertical integration and disintegration of computer firms: A history-friendly model of the coevolution of the computer and semiconductor industries. *Industrial and Corporate Change*, *17*(2), 197-231.

118. Mamuneas, T. P., & Nadiri, M. I. (1996). Public R&D policies and cost behavior of the US manufacturing industries. *Journal of Public Economics*, *63*(1), 57-81.

119. Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to empirics of economic growth. *The Quarterly Journal of Economics*, 107(2), 407-437.

120. Martin, S., & Scott, J. T. (2000). The nature of innovation market failure and the design of public support for private innovation. *Research Policy*,

29(4), 437-447.

121. Matsunaga, M. (2010). How to Factor-Analyze Your Data Right: Do's, Don'ts, and How-To's. *International journal of psychological research*, *3*(1), 97-110.

122. Mazzucato, M. (2016). From market fixing to market-creating: A new framework for innovation policy. *Industry and Innovation*, *23*(2), 140-156.

123. Mazzucato, M. (2018). Mission-oriented innovation policies: Challenges and opportunities. *Industrial and Corporate Change*, *27*(5), 803-815.

124. Mazzucato, M., & Semieniuk, G. (2017). Public financing of innovation: New questions. *Oxford Review of Economic Policy*, *33*(1), 24-48.

125. Metcalfe, S. J. (1995). Technology systems and technology policy in an evolutionary framework. *Cambridge Journal of Economics*, *19*(1), 25-46.

126. Metcalfe, S. J. (2003). Equilibrium and evolutionary foundations of competition and technology policy: New perspectives on the division of labour and the innovation process. In P. Pelikan & G. Wegner (Eds.), *The evolutionary analysis of economic policy*. Cheltenham, UK: Edward Elgar Publishing.

127. Metcalfe, S. J., & Foster, J. (2010). Evolutionary growth theory. In M. Setterfield (Ed.), *Handbook of alternative theories of economic growth* (pp. 64-95). Cheltenham, UK: Edward Elgar Publishing.

128. Metcalfe, S. J., & Ramlogan, R. (2008). Innovation systems and the competitive process in developing economies. *The Quarterly Review of Economics and Finance, 48*(2), 433-446.

129. Milesi-Ferretti, G. M., Perotti, R., & Rostagno, M. (2002). Electoral systems and public spending. *The Quarterly Journal of Economics*, *117*(2), 609-657.

130. Minford, L. (2015). *The macroeconomic effects of UK tax, regulation and R&D subsidies: Testing endogenous growth hypotheses in an open economy DSGE model* (Doctoral dissertation). Cardiff Business School, Cardiff Business School. Retrieved from https://core.ac.uk/download/pdf/42523721.pdf

131. Minford, L., & Meenagh, D. (2018). Testing a model of UK growth – a causal role of R&D subsidies. *Cardiff Economics Working Papers E2018/3,*

Cardiff University, Cardiff Business School, Economics Section. Retrieved from http://carbsecon.com/wp/E2018_3.pdf

132. Minniti, A., & Venturini, F. (2017). The long-run growth effects of R&D policy. *Research Policy*, *46*(1), 316-326.

133. Moretti, E., Steinwender, C., & Van Reenen, J. (2016). *The intellectual spoils of war? Defense R&D, productivity and spillovers.* Presented at the 2016 American Economic Association Annual Meeting, San Francisco, California. Retrieved from https://eml.berkeley.edu/~moretti/military.pdf

134. Morini, M., & Pellegrino, S. (2015). Agent-based dynamic optimization of fiscal systems. In R. Boero, M. Morini, M. Sonnessa & P. Terna (Eds.), *Agent-based models of the economy* (pp. 184-197). London, UK: Palgrave Macmillan.

135. Moser, P. (2003). *How do patent laws influence innovation? Evidence from nineteenth-century world fairs. NBER Working Paper Series, working paper No. 9909.* National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w9909.pdf

136. Mulder, P., De Groot, H. L., & Hofkes, M. W. (2001). Economic growth and technological change: A comparison of insights from a neo-classical and an evolutionary perspective. *Technological Forecasting and Social Change, 68*(2), 151-171.

137. Müller, P. (2005). Exploring the knowledge filter: How entrepreneurship and university–industry relationships drive economic growth. *Research Policy*, *35*(10), 1499-1508.

138. Muscio, A., Reid, A., & Rivera Leon, L. (2015). An empirical test of the regional innovation paradox: Can smart specialisation overcome the paradox in Central and Eastern Europe? *Journal of Economic Policy Reform*, *18*(2), 153-171.

139. Nelson, R. R. (1959). The simple economics of basic scientific research. *Journal of Political Economy*, *67*(3), 297-306.

140. Nelson, R. R., Dosi, G., & Helfat, C. E. (2018). *Modern evolutionary economics: An overview*. Cambridge, UK: Cambridge University Press.

141. Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge, Massachusetts, US: The Belknap Press of Harvard University Press.

142. Newey, W. K., & West, K. D. (1986). *A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. NBER Technical Paper Series, technical working paper No. 55.* National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/t0055.pdf

143. Niininen, P. (2000). Effect of publicly and privately financed R&D on total factor productivity growth. *Finnish Economic Papers*, *13*(1), 56-68.

144. Nordhaus, W. D. (1969). An economic theory of technological change. *The American Economic Review*, *59*(2), 18-28.

145. OECD (2015). *Frascati Manual 2015: Guidelines for collecting and reporting data on research and experimental development, the measurement of scientific, technological and innovation activities.* Paris, France: OECD Publishing. Retrieved from https://doi.org/10.1787/9789264239012-en.

146. OECD (2018). *Main Science and Technology Indicators* [database]. Retrieved from

https://stats.oecd.org/

147. OECD & Eurostat (2018). *Oslo Manual 2018: Guidelines for collecting and reporting data on research and experimental development, the measurement of scientific, technological and innovation activities (4th ed.).* Paris, France: OECD Publishing/Luxembourg, Luxembourg: Eurostat. Retrieved from https://doi.org/10.1787/9789264304604-en

148. Oughton, C., Landabaso, M., & Morgan, K. (2002). The regional innovation paradox: Innovation policy and industrial policy. *The Journal of Technology Transfer*, *27*(1), 97-110.

149. Overton, R. C. (2001). Moderated multiple regression for interactions involving categorical variables: A statistical control for heterogeneous variance across two groups. *Psychological methods*, 6(3), 218-233.

150. Parto, S., Ciarli, T., & Arora, S. (2005). *Economic growth, innovation systems, and institutional change: A trilogy in five parts*. *MERIT Research Memoranda No. 021.* Maastricht, the Netherlands: MERIT, Maastricht Economic Research Institute on Innovation and Technology. Retrieved from https://cris.maastrichtuniversity.nl/portal/files/1746768/guid-b5a1f19b-acc6-43b5-82f1-0c5182d53cb7-ASSET1.0.pdf

151. Persson, T., & Tabellini, G. E. (2005). *The economic effects of constitutions*. Cambridge, Massachusetts, US: MIT press.

152. Persson, T., & Tabellini, G. (2008). Electoral systems and economic policy. In B. Weingast & D. Wittman (Eds.), *Oxford handbook of political economy*. Oxford, UK: Oxford University Press. Retrieved from https://www.researchgate.net/profile/Torsten_Persson/publication/255661732_Electoral_Systems_and_Economic_Policy/links/542a7d350cf277d58e8733c4.pdf

153. Piekkola, H. (2007). Public funding of R&D and growth: Firm-level evidence from Finland. *Economics of Innovation and New Technology*, *16*(3), 195-210.

154. Rallet, A., & Torre, A. (2017). Geography of innovation, proximity and beyond. In H. Bathelt, P. Cohendet, S. Henn & L. Simon (Eds.), *The Elgar companion to innovation and knowledge creation* (pp. 421-439). Cheltenham, UK: Edward Elgar Publishing.

155. Rao, N. (2015). *Do tax credits stimulate R&D spending? The effect of the R&D tax credit in its first decade. NYU Wagner research paper No. 2272174.* The Wagner School, New York University. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2272174

156. Rao, N. (2016). Do tax credits stimulate R&D spending? The effect of the R&D tax credit in its first decade. *Journal of Public Economics*, *140*, 1-12.

157. Rickard, S. J. (2015). Electoral systems and trade. In L. L. Martin (Ed.), *The Oxford handbook of the political economy of international trade* (pp. 280-297). Oxford, UK: Oxford University Press.

158. Rickard, S. J. (2017). Electoral systems and policy outcomes. In W. R. Thomson (Ed.), *Oxford research encyclopedia of politics*. Oxford, UK: Oxford University Press. Retrieved from https://oxfordre.com/politics/view/10.1093/acrefore/9780190228637.001.0001/acrefore-9780190228637-e-267?print=pdf

159. Reszketo, P. (2008). *How to reduce the chance of government failures? Types of failures and its remedies*. Paper presented at the 3rd Annual Doctoral Conference, Department of Political Science, European University, Budapest.

160. Rodríguez-Pose, A., & Crescenzi, R. (2008). Research and development, spillovers, innovation systems, and the genesis of regional

growth in Europe. *Regional Studies*, *42*(1), 51-67.

161. Rogers, M. (1998). *The definition and measurement of innovation*. *Melbourne Institute Working Paper No. 10/98.* Melbourne Institute of Applied Economic and Social Research, The University of Melbourne. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.4269&rep=rep1&type=pdf

162. Romer, P. M. (1986). Increasing returns and long-run growth. *The Journal of Political Economy, 94*(5), 1002-1037.

163. Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5), 71-102.

164. Romer, P. M. (1992). Two strategies for economic development: Using ideas and producing ideas. Paper presented at the *Proceedings of the World Bank Annual Conference on Development Economics, 1992* (pp. 63-91). Retrieved from http://documents.worldbank.org/curated/en/353181468739245145/pdf/multi0page.pdf

165. Runiewicz-Wardyn, M. (2013). The role of knowledge absorption and innovation capability in the technological change and economic growth of EU regions. *International Journal of Management and Economics*, *39*(1), 51-69.

166. Russo, A., Catalano, M., Gaffeo, E., Gallegati, M., & Napoletano, M. (2007). Industrial dynamics, fiscal policy and R&D: Evidence from a computational experiment. *Journal of Economic Behavior & Organization*, *64*(3), 426-447.

167. Samimi, A. J., & Alerasoul, S. M. (2009). R&D and economic growth: New evidence from some developing countries. *Australian Journal of Basic and Applied Sciences*, *3*(4), 3464-3469.

168. Santangelo, G. D. (2003). The evolutionary perspective on growth. In N. Salvadori (Ed.), *The theory of economic growth: A 'classical' perspective* (pp. 205-222). Cheltenham, UK: Edward Elgar Publishing.

169. Santos, J. F., & Catalão-Lopes, M. (2014). Does R&D matter for economic growth or vice-versa? An application to Portugal and other European countries. *Archives of Business Research*, *2*(3), 1-17.

170. Saviotti, P. P. (2003). Introduction. In P. P. Saviotti (Ed.), *Applied evolutionary economics: New empirical methods and simulation techniques*.

Cheltenham, UK: Edward Elgar Publishing.

171. Sbordone, A. M., Tambalotti, A., Rao, K., & Walsh, K. J. (2010). Policy analysis using DSGE models: An introduction. *Economic Policy Review*, *16*(2), 23-43.

172. Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, *47*(9), 1554-1567.

173. Schorfheide, F. (2011). *Estimation and evaluation of DSGE models: Progress and challenges NBER Working Paper Series, working paper No. 16781.* National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w16781.pdf

174. Schröter, A. (2009). *New rationales for innovation policy? A comparison of the systems of innovation policy approach and the neoclassical perspective. Jena Economic Research Paper Series, research paper No. 33.* Max Planck Institute of Economics. Retrieved from https://www.econstor.eu/bitstream/10419/31752/1/59955696X.PDF

175. Schumpeter, J. A. (1939). *Business Cycles: A Theoretical Historical and Statistical Analysis of the Capitalist Process*. New York, New York, US: McGraw Hill.

176. SCImago, (n. d.). *SJR – SCImago Journal & Country Rank* [Portal]. Retrieved from http://www.scimagojr.com

177. Segerstrom, P. S. (2000). The long-run growth effects of R&D subsidies. *Journal of Economic Growth*, *5*(3), 277-305.

178. Shieh, G. (2018). Power and sample size calculations for comparison of two regression lines with heterogeneous variances. *PloS One*, *13*(12), e0207745.

179. Silaghi, M. I. P., Alexa, D., Jude, C., & Litan, C. (2014). Do business and public sector research and development expenditures contribute to economic growth in Central and Eastern European countries? A dynamic panel estimation. *Economic Modelling*, *36*, 108-119.

180. Sirkin, R. M. (2006). *Statistics for the social sciences (3rd ed.)*. Thoasand Oaks, California, US: SAGE Publishing.

181. Smets, F., & Wouters, R. (2007). *Shocks and frictions in US business cycles: A Bayesian DSGE approach. European Central Bank*

Working Paper Series, working paper No. 722. European Central Bank. Retrieved from https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp722.pdf

182. Soete, L. L., & Ter Weel, B. J. (1999). Innovation, knowledge creation and technology policy: The case of the Netherlands. *De Economist*, *147*(3), 293-310.

183. Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics, 70*(1), 65-94.

184. Taagepera, R., & Qvortrup, M. (2012). Who gets what, when, how– through which electoral system? *European Political Science*, *11*(2), 244–258.

185. Tassey, G. (1997). *The economics of R&D policy*. Westport, Connecticut, US: Greenwood Publishing Group.

186. Taylor, M. S. (1994). TRIPS, trade, and growth. *International Economic Review*, *35*(2), 361-381.

187. Tether, B., Mina, A., Consoli, D., & Gagliardi, D. (2005). *A literature review on skills and innovation. How does successful innovation impact on the demand for skills and how do skills drive innovation. A CRIC report for The Department of Trade and Industry.* ESRC Centre for Research on Innovation and Competition, University of Manchester. Retrieved from https://pdfs.semanticscholar.org/f25b/956d1002734286479e103a6ef01795062cdb.pdf

188. Thompson, M. A., & Rushing, F. W. (1999). An empirical analysis of the impact of patent protection on economic growth: An extension. *Journal of Economic Development*, *24*(1), 67-76.

189. Tkacz, G. (2001). Neural network forecasting of Canadian GDP growth. *International Journal of Forecasting*, *17*(1), 57-69.

190. Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy*, *34*(8), 1203-1219.

191. Tomescu, C., & Stanescu, I. (2009). The absorption capacity of European Union funds for social inclusion. An analysis into the PHARE 2004-2005 grants beneficiaries. *Revista de Cercetare si Interventie Sociala*, *25*, 7-29.

192. Toner, P. (2011). *Workforce skills and innovation: An overview of major themes in the literature.* Paris, France: OECD Publishing. Retrieved

from https://www.oecd.org/sti/inno/46970941.pdf

193. Trippi, R. R., & Turban, E. (1992). *Neural networks in finance and investing: Using artificial intelligence to improve real world performance*. New York, New York, US: McGraw-Hill, Inc.

194. Uyarra, E., & Ramlogan, R. (2016). The impact of cluster policy on innovation. In J. Edler, A. Gök, P. Cunningham, & P. Shapira (Eds.), *Handbook of innovation policy impact* (pp. 196-238). Cheltenham, UK: Edward Elgar Publishing.

195. Van Beveren, I. (2012). Total factor productivity estimation: A practical review. *Journal of Economic Surveys*, *26*(1), 98-128.

196. Van Pottelsberghe de la Potterie, B., & Lichtenberg, F. (2001). Does foreign direct investment transfer technology across borders? *Review of Economics and Statistics*, *83*(3), 490-497.

197. Verspagen, B. (2001). *Economic growth and technological change: An evolutionary interpretation. OECD Science, Technology and Industry Working Papers, working paper No. 2001/01.* Paris, France: OECD Publishing. Retrieved from https://dx.doi.org/10.1787/703445834058

198. Vilys, M, Jakubavičius, A., & Damkus, J. (2008). Inovacijų politika: žinioms imlių pramonės sektorių kontekstas. *Ekonomika ir vadyba: aktualijos ir perspektyvos, 14*(3), 384-391.

199. Weingast, B. R. (1995). The economic role of political institutions: Market-preserving federalism and economic development. *Journal of Law, Economics, & Organization, 11*(1), 1-31.

200. Wensink, W., & de Vet, J. M. (2013). *Identifying and reducing corruption in public procurement in the EU: Development of a methodology to estimate the direct costs of corruption and other elements for an EU-evaluation mechanism in the area of anti-corruption.* European Commission. Retrieved from https://ec.europa.eu/anti-fraud/sites/antifraud/files/docs/body/identifying_reducing_corruption_in_public_procurement_en.pdf

201. Winter, B., & Nelson, R. (1974). Neoclassical versus evolutionary theories of economic growth: Critique and prospectus. *The Economic Journal, 84*(336), 886-905.

202. Witt, U. (2008). What is specific about evolutionary

economics? *Journal of Evolutionary Economics*, *18*(5), 547-575.

203. Woolthuis, R. K., Lankhuizen, M., & Gilsing, V. (2005). A system failure framework for innovation policy design. *Technovation*, *25*(6), 609-619.

APPENDIXES

Appendix 1. Correlation Matrix

Table 1. Correlation matrix

Electoral	Absorption	GovCrea	Output	PrivCrea	
1.0000	-0.2340	-0.3946	-0.4473	-0.2395	Electoral
	1.0000	0.6132	0.3730	0.6012	Absorption
		1.0000	0.7396	0.7989	GovCrea
			1.0000	0.5857	Output
				1.0000	PrivCrea
Transfer	l_GDP_PPP	l_ALF	l_GFCF	elABS	
-0.5666	-0.5697	-0.5438	-0.5544	-0.0649	Electoral
0.2388	0.2278	0.0843	0.1988	0.9832	Absorption
0.6321	0.5633	0.4063	0.5691	0.5560	GovCrea
0.7646	0.8370	0.7472	0.8437	0.3011	Output
0.4230	0.4153	0.2982	0.4328	0.5748	PrivCrea
1.0000	0.8386	0.7607	0.8320	0.1370	Transfer
	1.0000	0.9661	0.9938	0.1288	l_GDP_PPP
		1.0000	0.9760	-0.0126	l_ALF
			1.0000	0.0964	l_GFCF
				1.0000	elABS
	elGOV	elTRA	GDPALF	l_CAPALF	
	-0.0942	-0.1139	-0.1752	-0.0501	Electoral
	0.6168	0.1526	0.5089	0.3598	Absorption
	0.8964	0.4663	0.6383	0.5465	GovCrea
	0.6426	0.6536	0.4011	0.3106	Output
	0.7377	0.3184	0.4350	0.3907	PrivCrea
	0.4292	0.8276	0.4518	0.4082	Transfer
	0.3632	0.6461	0.2628	0.1773	l_GDP_PPP
	0.1993	0.5702	0.0155	-0.0170	l_ALF
	0.3584	0.6509	0.2379	0.2013	l_GFCF
	0.6179	0.1370	0.4831	0.3534	elABS
	1.0000	0.4968	0.6137	0.5428	elGOV
		1.0000	0.4108	0.4491	elTRA
			1.0000	0.8517	GDPALF
				1.0000	l_CAPALF

Appendix 2. Panel Diagnostics Tests

Table 1. Diagnostics tests for panel data analysis method selection

Dependent variable	*Joint significance of differing group means test*	*Breusch-Pagan test*	*Hausman test*	*Conclusion*
Log GDP	$p < 0.001$	$p < 0.001$	$p < 0.001$	Fixed effects estimation preferred
Log GDP per unit of ALF	$p < 0.001$	$p < 0.001$	$p < 0.001$	Fixed effects estimation preferred
Innovation output index	$p < 0.001$	$p < 0.001$	-	Random effect estimation preferred
Knowledge absorption index	$p < 0.001$	$p < 0.001$	-	Random effect estimation preferred
Technology transfer index	$p < 0.001$	$p < 0.001$	-	Random effect estimation preferred
Government knowledge creation index	$p < 0.001$	$p < 0.001$	-	Random effect estimation preferred

Appendix 3. Heteroskedasticity Tests

Table 1. Heteroskedasticity tests

Dependent variable	*White's test*	*Wald's test (groupwise heteroskedasticity)*	*Conclusion*
Log GDP	$p < 0.001$	$p < 0.001$	Data are heteroskedastic, needing robust standard errors or WLS estimation
Log GDP (first differences)	$p = 0.164512$	$p < 0.001$	Data are groupwise heteroskedastic, needing robust standard errors or WLS estimation
Log GDP per unit of ALF	$p < 0.001$	$p < 0.001$	Data are heteroskedastic, needing robust standard errors or WLS estimation
Log GDP per unit of ALF (first differences)	$p = 0.089531$	$p < 0.001$	Data are groupwise heteroskedastic, needing robust standard errors or WLS estimation
Innovation output index	$p < 0.001$	$p < 0.001$	Data are heteroskedastic, needing robust standard errors or WLS estimation
Knowledge absorption index	$p = 0.488105$	$p < 0.001$	Data are groupwise heteroskedastic, needing robust standard errors or WLS estimation
Technology transfer index	$p = 0.999996$	$p < 0.001$	Data are groupwise heteroskedastic, needing robust standard errors or WLS estimation
Government knowledge creation index	0.777655	$p < 0.001$	Data are groupwise heteroskedastic, needing robust standard errors or WLS estimation

Appendix 4. Normality of Residuals Tests

Table 1. Normality of residual tests for estimated models

Dependent variable	*Test for null hypothesis of normal distribution*	*Conclusion*
Log GDP	$p < 0.0001$	Residuals are not normally distributed
Log GDP (first differences)	$p < 0.0001$	Residuals are not normally distributed
Log GDP per unit of ALF	$p < 0.0001$	Residuals are not normally distributed
Log GDP per unit of ALF (first differences)	$p = 0.00211$	Residuals are not normally distributed
Innovation output index	$p < 0.0001$	Residuals are not normally distributed
Knowledge absorption index	$p = 0.00620$	Residuals are not normally distributed
Technology transfer index	$p = 0.05482$	Residuals are not normally distributed
Government knowledge creation index	$p < 0.0001$	Residuals are not normally distributed

Appendix 5. Multicollinearity Tests

Table 1. Variance inflation factors test for the estimated models

Model (dependent variable)	*Results*
Log GDP	In the initial model, the indicators of labour force and capital had VIF values >10, leading to multicollinearity problem. The model has been tested with these indicators separately, leaving gross fixed capital formation, because active labour force indicator did not have statistically significant effect on the dependent variable.
Log GDP (first differences)	All VIF values are <10, therefore, there is no multicollinearity in the model.
Log GDP per unit of ALF	All VIF values are <10, therefore, there is no multicollinearity in the model.
Log GDP per unit of ALF (first differences)	All VIF values are <10, therefore, there is no multicollinearity in the model.
Innovation output index	There are variables with VIF > 10. However, this is due to the use of interaction variables to capture the mediation effect of electoral systems. Therefore, these variables are kept and the model is estimated.
Knowledge absorption index	All VIF values are <10, therefore, there is no multicollinearity in the model.
Technology transfer index	All VIF values are <10, therefore, there is no multicollinearity in the model.
Government knowledge creation index	All VIF values are <10, therefore, there is no multicollinearity in the model.

Appendix 6. Autocorrelation Tests

Table 1. Durbin-Watson test

Model (dependent variable)	*Durbin-Watson statistic*	*Conclusion*
Log GDP	0.538117	There is autocorrelation in the data, requiring addressing (e.g. HAC standard errors).
Log GDP (first differences)	1.802771	The level of autocorrelation is acceptable.
Log GDP per unit of ALF	0.310814	There is autocorrelation in the data, requiring addressing (e.g. HAC standard errors).
Log GDP per unit of ALF (first differences)	1.599045	The level of autocorrelation is acceptable.
Innovation output index	1.4976	The level of autocorrelation is close to acceptable. However, due to heteroskedasticity and slight autocorrelation, HAC standard errors could be used.
Knowledge absorption index	0.061367	There is autocorrelation in the data, requiring addressing (e.g. HAC standard errors).
Technology transfer index	0.154314	There is autocorrelation in the data, requiring addressing (e.g. HAC standard errors).
Government knowledge creation index	0.032201	There is autocorrelation in the data, requiring addressing (e.g. HAC standard errors).

Appendix 7. Alternative Estimation Methods

Table 1. Dependent variable: log GDP, pooled OLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	2.13787	0.333341	6.413	<0.0001
GFCF (log, lag=1)	0.954789	0.0292554	32.64	<0.0001
Innovation output index (lag=1)	−0.00169561	0.0579065	−0.02928	0.9769
Technology transfer index (lag=1)	0.206002	0.0701370	2.937	0.0070
Knowledge absorption index (lag=1)	−0.0775037	0.0483849	−1.602	0.1218
TD2	−0.0668397	0.0486494	−1.374	0.1817
TD3	−0.0478367	0.0483617	−0.9891	0.3321
TD4	−0.0260498	0.0488071	−0.5337	0.5982
TD5	−0.0597663	0.0502249	−1.190	0.2452
TD6	−0.0448204	0.0475561	−0.9425	0.3550
TD7	−0.0989793	0.0475216	−2.083	0.0477
TD8	−0.145080	0.0421354	−3.443	0.0020
TD9	−0.213789	0.0335963	−6.363	<0.0001
TD10	−0.0424544	0.0369239	−1.150	0.2611
TD11	0.0178999	0.0352781	0.5074	0.6163
TD12	−0.0275772	0.0231973	−1.189	0.2457
TD13	0.0122729	0.0132467	0.9265	0.3631
TD14	−0.0775037	0.0483849	−1.602	0.1218
Adjusted R^2				0.992076
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 2. Dependent variable: log GDP, random effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*z*	*p-value*
Constant	4.52722	0.502941	9.002	<0.0001
GFCF (log, lag=1)	0.742530	0.0435497	17.05	<0.0001
Innovation output index (lag=1)	0.177799	0.0352652	5.042	<0.0001
Technology transfer index (lag=1)	0.216877	0.0518981	4.179	<0.0001
Knowledge absorption index (lag=1)	0.110708	0.0332473	3.330	0.0009
TD2	−0.182098	0.0471433	−3.863	0.0001
TD3	−0.149416	0.0480791	−3.108	0.0019
TD4	−0.123289	0.0478990	−2.574	0.0101
TD5	−0.103475	0.0451270	−2.293	0.0218
TD6	−0.119141	0.0436500	−2.729	0.0063
TD7	−0.0978057	0.0370358	−2.641	0.0083
TD8	−0.111182	0.0310659	−3.579	0.0003
TD9	−0.150844	0.0291441	−5.176	<0.0001
TD10	−0.207355	0.0239975	−8.641	<0.0001
TD11	−0.0691495	0.0287903	−2.402	0.0163
TD12	−0.0102102	0.0261108	−0.3910	0.6958
TD13	−0.0413593	0.0176476	−2.344	0.0191
TD14	−0.00119201	0.0107732	−0.1106	0.9119
Between R^2				0.0124792
Within R^2				0.00313313
Mean theta				0.865476
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 3. Dependent variable: log GDP, groupwise WLS estimation

Independent variable / statistic	Coefficient	Std. Error	t-ratio	p-value
Constant	2.36271	0.0919994	25.68	<0.0001
GFCF (log, lag=1)	0.933308	0.00809653	115.3	<0.0001
Innovation output index (lag=1)	0.0155619	0.0152535	1.020	0.3084
Technology transfer index (lag=1)	0.233701	0.0245220	9.530	<0.0001
Knowledge absorption index (lag=1)	0.0459542	0.0101072	4.547	<0.0001
TD2	−0.0841486	0.0246495	−3.414	0.0007
TD3	−0.0644910	0.0245885	−2.623	0.0091
TD4	−0.0500702	0.0245420	−2.040	0.0421
TD5	−0.0136956	0.0245718	−0.5574	0.5776
TD6	−0.0337205	0.0245132	−1.376	0.1699
TD7	−0.0303974	0.0244221	−1.245	0.2141
TD8	−0.0740318	0.0240324	−3.081	0.0022
TD9	−0.116284	0.0240880	−4.827	<0.0001
TD10	−0.196782	0.0239173	−8.228	<0.0001
TD11	−0.0369112	0.0239227	−1.543	0.1238
TD12	0.0185047	0.0238855	0.7747	0.4390
TD13	−0.0336504	0.0239042	−1.408	0.1601
TD14	0.0163446	0.0238093	0.6865	0.4929
Within R^2				0.996702
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 4. Dependent variable: log GDP per unit of ALF, pooled OLS estimation

Independent variable / statistic	Coefficient	Std. Error	t-ratio	p-value
Constant	2.31834	0.243735	9.512	<0.0001
GFCF per unit of ALF (log, lag=1)	0.761201	0.0869002	8.759	<0.0001
Innovation output index (lag=1)	−0.0131938	0.0868795	−0.1519	0.8805
Technology transfer index (lag=1)	0.187434	0.0923772	2.029	0.0532
Knowledge absorption index (lag=1)	0.0955150	0.0289574	3.298	0.0029
TD2	−0.429751	0.0561307	−7.656	<0.0001
TD3	−0.379914	0.0514298	−7.387	<0.0001
TD4	−0.330048	0.0525544	−6.280	<0.0001
TD5	−0.280468	0.0498110	−5.631	<0.0001
TD6	−0.278693	0.0485851	−5.736	<0.0001
TD7	−0.231321	0.0468709	−4.935	<0.0001
TD8	−0.233398	0.0402496	−5.799	<0.0001
TD9	−0.233742	0.0334088	−6.996	<0.0001
TD10	−0.261910	0.0264153	−9.915	<0.0001
TD11	−0.104018	0.0255525	−4.071	0.0004
TD12	−0.0353203	0.0262634	−1.345	0.1907
TD13	−0.0597706	0.0181134	−3.300	0.0029
TD14	−0.00509226	0.0122369	−0.4161	0.6809
Adjusted R^2				0.882969
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 5. Dependent variable: log GDP, random effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*z*	*p-value*
Constant	3.24682	0.311240	10.43	<0.0001
GFCF per unit of ALF (log, lag=1)	0.420957	0.111159	3.787	0.0002
Innovation output index (lag=1)	0.0951083	0.0498871	1.906	0.0566
Technology transfer index (lag=1)	0.112138	0.0301804	3.716	0.0002
Knowledge absorption index (lag=1)	0.114555	0.0253456	4.520	<0.0001
TD2	−0.528403	0.0528506	−9.998	<0.0001
TD3	−0.466228	0.0479294	−9.727	<0.0001
TD4	−0.416123	0.0476271	−8.737	<0.0001
TD5	−0.360916	0.0414037	−8.717	<0.0001
TD6	−0.333837	0.0395954	−8.431	<0.0001
TD7	−0.268800	0.0365791	−7.348	<0.0001
TD8	−0.224214	0.0192655	−11.64	<0.0001
TD9	−0.204969	0.0193543	−10.59	<0.0001
TD10	−0.228000	0.0178954	−12.74	<0.0001
TD11	−0.125894	0.0143531	−8.771	<0.0001
TD12	−0.0622857	0.0162142	−3.841	0.0001
TD13	−0.0638931	0.0110762	−5.768	<0.0001
TD14	−0.0146811	0.00934765	−1.571	0.1163
Between variance				0.0110514
Within variance				0.00564253
Mean theta				0.809952
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 6. Dependent variable: log GDP per unit of ALF, groupwise WLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	2.46951	0.0556767	44.35	<0.0001
GFCF per unit of ALF (log, lag=1)	0.698619	0.0198380	35.22	<0.0001
Innovation output index (lag=1)	0.0519333	0.0184552	2.814	0.0052
Technology transfer index (lag=1)	0.132364	0.0210818	6.279	<0.0001
Knowledge absorption index (lag=1)	0.0921187	0.00892610	10.32	<0.0001
TD2	−0.424500	0.0238006	−17.84	<0.0001
TD3	−0.366421	0.0237446	−15.43	<0.0001
TD4	−0.316476	0.0236712	−13.37	<0.0001
TD5	−0.265637	0.0237297	−11.19	<0.0001
TD6	−0.262272	0.0234377	−11.19	<0.0001
TD7	−0.216235	0.0232561	−9.298	<0.0001
TD8	−0.198743	0.0226198	−8.786	<0.0001
TD9	−0.195348	0.0226405	−8.628	<0.0001
TD10	−0.232929	0.0226354	−10.29	<0.0001
TD11	−0.103087	0.0225963	−4.562	<0.0001
TD12	−0.0424770	0.0225785	−1.881	0.0608
TD13	−0.0640823	0.0225802	−2.838	0.0048
TD14	−0.00141378	0.0225318	−0.06275	0.9500
Adjusted R^2				0.951054
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 7. Dependent variable: innovation output index, pooled OLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.255895	0.0851915	3.004	0.0058
Knowledge absorption index (lag=1)	−0.0318724	0.0682466	−0.4670	0.6444
Government knowledge creation index (lag=1)	−0.161381	0.154162	−1.047	0.3048
Private knowledge creation index (lag=1)	0.681265	0.127356	5.349	<0.0001
Technology transfer index (lag=1)	0.175228	0.107631	1.628	0.1156
Electoral system (proportional=1)	−0.239643	0.104392	−2.296	0.0300
*Proportional system * Knowledge absorption index (lag=1)*	−0.0634638	0.133396	−0.4758	0.6382
*Proportional system * Government knowledge creation index (lag=1)*	0.625844	0.217930	2.872	0.0080
*Proportional system * Technology transfer index (lag=1)*	0.0101176	0.210855	0.04798	0.9621
Adjusted R^2				0.719924
P-value(F)				< 0.0001
Number of obs.	371 (27 cross-sectional units, with time series length between 8 and 14)			

Table 8. Dependent variable: innovation output index, groupwise WLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.244600	0.0406399	6.019	<0.0001
Knowledge absorption index (lag=1)	−0.0307311	0.160031	−0.1920	0.8478
Government knowledge creation index (lag=1)	−0.158912	0.0752355	−2.112	0.0354
Private knowledge creation index (lag=1)	0.705003	0.0763840	9.230	<0.0001
Technology transfer index (lag=1)	0.147459	0.0341690	4.316	<0.0001
Electoral system (proportional=1)	−0.221865	0.0417249	−5.317	<0.0001
*Proportional system * Knowledge absorption index (lag=1)*	0.0136495	0.162213	0.08415	0.9330
*Proportional system * Government knowledge creation index (lag=1)*	0.502098	0.0734060	6.840	<0.0001
*Proportional system * Technology transfer index (lag=1)*	0.0179413	0.0831245	0.2158	0.8292
Adjusted R^2				0.938434
P-value(F)				< 0.0001
Number of obs.	371 (27 cross-sectional units, with time series length between 8 and 14)			

Table 9. Dependent variable: knowledge absorption index, pooled OLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.476770	0.0383614	12.43	<0.0001
Prop	−0.385419	0.109475	−3.521	0.0016
TD1	−0.354238	0.0548041	−6.464	<0.0001
TD2	−0.339667	0.0551341	−6.161	<0.0001
TD3	−0.319606	0.0496282	−6.440	<0.0001
TD4	−0.298649	0.0511251	−5.842	<0.0001
TD5	−0.288804	0.0507136	−5.695	<0.0001
TD6	−0.257846	0.0454367	−5.675	<0.0001
TD7	−0.264966	0.0543589	−4.874	<0.0001
TD8	−0.210139	0.0412223	−5.098	<0.0001
TD9	−0.165604	0.0358417	−4.620	<0.0001
TD10	−0.159273	0.0312732	−5.093	<0.0001
TD11	−0.130002	0.0370972	−3.504	0.0017
TD12	−0.0805820	0.0285033	−2.827	0.0089
TD13	−0.0573668	0.0313959	−1.827	0.0792
TD14	−0.0171130	0.0242055	−0.7070	0.4859
Adjusted R^2				0.068213
P-value(F)				<0.0001
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 10. Dependent variable: knowledge absorption index, WLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.451321	0.0216591	20.84	<0.0001
Prop	−0.381335	0.0113144	−33.70	<0.0001
TD1	−0.326440	0.0291220	−11.21	<0.0001
TD2	−0.295357	0.0291220	−10.14	<0.0001
TD3	−0.296414	0.0291220	−10.18	<0.0001
TD4	−0.254734	0.0291220	−8.747	<0.0001
TD5	−0.217760	0.0291220	−7.477	<0.0001
TD6	−0.223597	0.0291220	−7.678	<0.0001
TD7	−0.206483	0.0285929	−7.221	<0.0001
TD8	−0.201533	0.0285929	−7.048	<0.0001
TD9	−0.125105	0.0285929	−4.375	<0.0001
TD10	−0.134477	0.0285929	−4.703	<0.0001
TD11	−0.117445	0.0285929	−4.108	<0.0001
TD12	−0.0557910	0.0285929	−1.951	0.0518
TD13	−0.0258157	0.0285929	−0.9029	0.3672
TD14	0.00376147	0.0285929	0.1316	0.8954
Adjusted R^2				0.790429
P-value(F)				<0.0001
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 11. Dependent variable: technology transfer index, pooled OLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.558269	0.237848	2.347	0.0268
Prop	−0.853180	0.247903	−3.442	0.0020
TD2	−0.0189412	0.0367602	−0.5153	0.6107
TD3	−0.0346797	0.0492359	−0.7044	0.4875
TD4	0.0197028	0.0347879	0.5664	0.5760
TD5	0.0626979	0.0351044	1.786	0.0858
TD6	0.130024	0.0345036	3.768	0.0009
TD7	0.213502	0.0382699	5.579	<0.0001
TD8	0.278360	0.0419503	6.635	<0.0001
TD9	0.267449	0.0463374	5.772	<0.0001
TD10	0.231769	0.0456245	5.080	<0.0001
TD11	0.246455	0.0462643	5.327	<0.0001
TD12	0.300819	0.0428742	7.016	<0.0001
TD13	0.244477	0.0514423	4.752	<0.0001
TD14	0.266863	0.0472238	5.651	<0.0001
TD15	0.198303	0.0982710	2.018	0.0540
Adjusted R^2				0.357168
P-value(F)				<0.0001
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 12. Dependent variable: technology transfer index, WLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.747215	0.0466209	16.03	<0.0001
Prop	−0.785793	0.0313871	−25.04	<0.0001
TD1	−0.273324	0.0523075	−5.225	<0.0001
TD2	−0.293591	0.0523075	−5.613	<0.0001
TD3	−0.299124	0.0523075	−5.719	<0.0001
TD4	−0.260326	0.0523075	−4.977	<0.0001
TD5	−0.210870	0.0523075	−4.031	<0.0001
TD6	−0.131571	0.0523075	−2.515	0.0123
TD7	−0.0744141	0.0521938	−1.426	0.1548
TD8	−0.0148922	0.0521938	−0.2853	0.7755
TD9	−0.00267401	0.0521938	−0.05123	0.9592
TD10	−0.0542774	0.0521938	−1.040	0.2990
TD11	−0.0418108	0.0521938	−0.8011	0.4236
TD12	0.0200036	0.0521938	0.3833	0.7017
TD13	−0.0310110	0.0521938	−0.5942	0.5528
TD14	−0.00147105	0.0521938	−0.02818	0.9775
Adjusted R^2				0.657992
P-value(F)				<0.0001
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 13. Dependent variable: government knowledge creation index, pooled OLS estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.223509	0.270260	0.8270	0.4158
Prop	−0.611963	0.285889	−2.141	0.0419
TD1	0.0953491	0.0410044	2.325	0.0281
TD2	0.125509	0.0379876	3.304	0.0028
TD3	0.159699	0.0413028	3.867	0.0007
TD4	0.153761	0.0402093	3.824	0.0007
TD5	0.181836	0.0395547	4.597	<0.0001
TD6	0.217875	0.0367955	5.921	<0.0001
TD7	0.252070	0.0406096	6.207	<0.0001
TD8	0.296480	0.0387865	7.644	<0.0001
TD9	0.340591	0.0422568	8.060	<0.0001
TD10	0.356880	0.0431664	8.268	<0.0001
TD11	0.375776	0.0379751	9.895	<0.0001
TD12	0.423253	0.0413245	10.24	<0.0001
TD13	0.446047	0.0438306	10.18	<0.0001
TD14	0.480212	0.0556666	8.627	<0.0001
Adjusted R^2	0.203489			
P-value(F)	<0.0001			
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 14. Dependent variable: government knowledge creation index, WLS effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.00459008	0.0651857	0.07042	0.9439
Prop	−0.401939	0.0572225	−7.024	<0.0001
TD1	0.0624739	0.0474675	1.316	0.1889
TD2	0.103269	0.0474675	2.176	0.0302
TD3	0.158157	0.0474675	3.332	0.0009
TD4	0.153796	0.0474675	3.240	0.0013
TD5	0.193700	0.0474675	4.081	<0.0001
TD6	0.261916	0.0463965	5.645	<0.0001
TD7	0.324249	0.0463965	6.989	<0.0001
TD8	0.340607	0.0463965	7.341	<0.0001
TD9	0.377503	0.0463965	8.136	<0.0001
TD10	0.390396	0.0463965	8.414	<0.0001
TD11	0.412779	0.0463965	8.897	<0.0001
TD12	0.452902	0.0463965	9.762	<0.0001
TD13	0.449749	0.0463965	9.694	<0.0001
TD14	0.486132	0.0464536	10.46	<0.0001
Adjusted R^2	0.467397			
P-value(F)	<0.0001			
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Appendix 8. Comparison Tests for Models with and without Time Dummies

Table 1. Tests for selecting models with or without time dummies

Dependent variable	*Without time dummies*		*With time dummies*	
	Log-likelihood	Akaike	Log-likelihood	Akaike
Log GDP	359.9466	−659.8932	545.5295	−1005.059
Log GDP per unit of ALF	248.7900	−437.5799	440.5181	−795.0363
Innovation output index	−163.3389	344.6778	−201.8943	447.7886
Knowledge absorption index	−563.2960	1130.592	−557.5651	1147.130
Technology transfer index	−561.9733	1127.947	−556.9598	1145.920
Government knowledge creation index	−556.8041	1117.608	−552.5134	1137.027

Appendix 9. Main Models with Time Dummy Results

Table 1. Dependent variable: log GDP, fixed effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	7.81405	0.512748	15.24	<0.0001
GFCF (log, lag=1)	0.452018	0.0453538	9.966	<0.0001
Innovation output index (lag=1)	0.113412	0.0317327	3.574	0.0015
Technology transfer index (lag=1)	0.0924333	0.0305999	3.021	0.0057
Knowledge absorption index (lag=1)	0.0573173	0.0323023	1.774	0.0882
TD2	−0.455952	0.0439074	−10.38	<0.0001
TD3	−0.404561	0.0425145	−9.516	<0.0001
TD4	−0.364538	0.0408320	−8.928	<0.0001
TD5	−0.313977	0.0343417	−9.143	<0.0001
TD6	−0.290665	0.0348408	−8.343	<0.0001
TD7	−0.226474	0.0311243	−7.276	<0.0001
TD8	−0.190961	0.0206782	−9.235	<0.0001
TD9	−0.180136	0.0167683	−10.74	<0.0001
TD10	−0.218208	0.0130835	−16.68	<0.0001
TD11	−0.118647	0.0131899	−8.995	<0.0001
TD12	−0.0576653	0.0154975	−3.721	0.0010
TD13	−0.0591956	0.0103101	−5.742	<0.0001
TD14	−0.0149029	0.00678303	−2.197	0.0375
Within R^2				0.965997
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 2. Dependent variable: log GDP, fixed effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	3.41769	0.334767	10.21	<0.0001
GFCF per unit of ALF (log, lag=1)	0.360274	0.120500	2.990	0.0062
Innovation output index (lag=1)	0.113135	0.0565252	2.001	0.0563
Technology transfer index (lag=1)	0.0827672	0.0376792	2.197	0.0375
Knowledge absorption index (lag=1)	0.0897837	0.0317294	2.830	0.0091
TD2	−0.560535	0.0654273	−8.567	<0.0001
TD3	−0.496069	0.0609376	−8.141	<0.0001
TD4	−0.445644	0.0604069	−7.377	<0.0001
TD5	−0.387799	0.0509844	−7.606	<0.0001
TD6	−0.355232	0.0474851	−7.481	<0.0001
TD7	−0.284997	0.0416570	−6.842	<0.0001
TD8	−0.230849	0.0225350	−10.24	<0.0001
TD9	−0.205283	0.0200527	−10.24	<0.0001
TD10	−0.226308	0.0181309	−12.48	<0.0001
TD11	−0.134532	0.0152659	−8.813	<0.0001
TD12	−0.0707528	0.0162639	−4.350	0.0002
TD13	−0.0659886	0.00992619	−6.648	<0.0001
TD14	−0.0178651	0.00885745	−2.017	0.0546
Adjusted R^2				0.922135
P-value(F)				<0.0001
Number of obs.	357 (26 cross-sectional units, with time series length between 8 and 14)			

Table 3. Dependent variable: knowledge absorption index, random effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.459087	0.0333949	13.75	<0.0001
Prop	−0.387695	0.107711	−3.599	0.0003
TD1	−0.336306	0.0518295	−6.489	<0.0001
TD2	−0.321735	0.0519335	−6.195	<0.0001
TD3	−0.301674	0.0456263	−6.612	<0.0001
TD4	−0.280717	0.0469271	−5.982	<0.0001
TD5	−0.270872	0.0466388	−5.808	<0.0001
TD6	−0.239914	0.0399560	−6.004	<0.0001
TD7	−0.245259	0.0497679	−4.928	<0.0001
TD8	−0.190432	0.0345896	−5.505	<0.0001
TD9	−0.145897	0.0278289	−5.243	<0.0001
TD10	−0.139566	0.0237853	−5.868	<0.0001
TD11	−0.110295	0.0315886	−3.492	0.0005
TD12	−0.0608749	0.0210844	−2.887	0.0039
TD13	−0.0376597	0.0253247	−1.487	0.1370
TD14	0.00259409	0.0148114	0.1751	0.8610
Between R^2				0.247911
Within R^2				0.0182951
Mean theta				0.929191
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 4. Dependent variable: technology absorption index, random effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.567563	0.237569	2.389	0.0169
Prop	−0.847205	0.247932	−3.417	0.0006
TD1	−0.0189412	0.0367602	−0.5153	0.6064
TD2	−0.0346797	0.0492359	−0.7044	0.4812
TD3	0.0197028	0.0347879	0.5664	0.5711
TD4	0.0626979	0.0351044	1.786	0.0741
TD5	0.130024	0.0345036	3.768	0.0002
TD6	0.198896	0.0341638	5.822	<0.0001
TD7	0.263755	0.0381720	6.910	<0.0001
TD8	0.252844	0.0433540	5.832	<0.0001
TD9	0.217164	0.0424453	5.116	<0.0001
TD10	0.231850	0.0431479	5.373	<0.0001
TD11	0.286214	0.0386498	7.405	<0.0001
TD12	0.229872	0.0488644	4.704	<0.0001
TD13	0.252258	0.0457347	5.516	<0.0001
TD14	0.175737	0.0972614	1.807	0.0708
Between R^2				0.13139
Within R^2				0.0221364
Mean theta				0.893357
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Table 5. Dependent variable: government knowledge creation index, random effects estimation

Independent variable / statistic	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*
Constant	0.226835	0.270121	0.8398	0.4010
Prop	−0.611469	0.285467	−2.142	0.0322
TD1	0.0953491	0.0410044	2.325	0.0201
TD2	0.125509	0.0379876	3.304	0.0010
TD3	0.159699	0.0413028	3.867	0.0001
TD4	0.153761	0.0402093	3.824	0.0001
TD5	0.181836	0.0395547	4.597	<0.0001
TD6	0.214109	0.0360743	5.935	<0.0001
TD7	0.248305	0.0400175	6.205	<0.0001
TD8	0.292714	0.0385443	7.594	<0.0001
TD9	0.336825	0.0422473	7.973	<0.0001
TD10	0.353115	0.0434527	8.126	<0.0001
TD11	0.372010	0.0382452	9.727	<0.0001
TD12	0.419487	0.0418828	10.02	<0.0001
TD13	0.442282	0.0443476	9.973	<0.0001
TD14	0.460449	0.0454404	10.13	<0.0001
Between R^2				0.194871
Within R^2				0.00878044
Mean theta				0.944617
Number of obs.	398 (27 cross-sectional units, with time series length between 9 and 15)			

Appendix 10. Country Abbreviations

Table 1. Country abbreviations

Abbreviation	Country name	Abbreviation	Country name
AUT	Austria	ISL	Iceland
BEL	Belgium	ITA	Italy
CAN	Canada	LUX	Luxembourg
CHE	Switzerland	NLD	Netherlands
CZE	Czech Republic	NOR	Norway
DEU	Germany	NZL	New Zealand
DNK	Denmark	POL	Poland
ESP	Spain	PRT	Portugal
EST	Estonia	ROU	Romania
FIN	Finland	SVK	Slovakia
GBR	United Kingdom	SVN	Slovenia
GRC	Greece	SWE	Sweden
HUN	Hungary	USA	United States
IRL	Ireland		

Pijus Krūminas

The Assessment of the Relationship Between Innovation Policy and Economic Growth in the Context of Electoral Institutions

Daktaro disertacija

Išleido ISM Vadybos ir ekonomikos universitetas, Aušros Vartų g. 7A, LT-01304 Vilnius

Spausdino leidyklos „Technologija“ spaustuvė, Studentų g. 54, LT-51424 Kaunas

26 leidyb. aps. l. Tiražas 16 egz. Užsakymas 217