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ICT corporation within the modern market economy: benefits and side effects of hosting "Silicon Valley"

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Master's Thesis

Prague, August 2022

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Master’s Thesis Proposal

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Proposed Topic:

ICT corporation within the modern market economy: benefits and side effects of hosting "Silicon Valley"

Preliminary scope of work:

Research question and motivation

The growth of the IT industry in the last couple of decades caused by rapid technological changes within the field of collection and distribution of information has led to a serious shift in the modern policymaking implemented by governments who are hosting large IT corporations. Tax benefits, subsidies, labor law indulgences, and government purchases are the possible ways how a country can become more attractive for “Google” to establish its new facility. Empirical studies show that while Science Parks do not contribute to the growth directly, they can increase the investment attractiveness and income flows for both ICT and non-ICT companies of the entire region. This research aims to show and explain under which conditions IT integration can become profitable both for the governments and firms.

Contribution

The aim of my paper is to extend the knowledge about the role of ICT corporations in the modern economy. The paper will analyze the empirical evidence that the growth of the ICT sector is leading to the growth of the GDP and study the simplified model to explain the underlying relationship. While the majority of articles that study similar topics focus mostly on the growth possibilities of ICT corporations and use empirical data to prove their hypotheses, I will examine the effects using both empirical and theoretical approaches.

Methodology

The relevant literature on the studied topic can be divided into two main categories: empirical and theoretical articles. While the first group is more popular among the researchers, the scope of such studies is limited by local microeconomic data which makes it complicated to draw universal conclusions and give political advice that will be suitable for countries of a certain group. Thus, my research is aimed to study the relationship between growth and ICT on the countries level data (European Union countries) using panel data analysis and build a proper theoretical general equilibrium model to explain empirical findings. The model will focus on the firms that produce innovative goods which later can be used for the production of consumption goods and on how such firms affect the economic relationship.

Outline

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2. Relevant literature
3. ICT industry: key features and history
4. Empirical evidence
5. Theoretical model
5.1. Equilibrium
5.2. Comparative statics
5.3. Results and discussion
6. Conclusions

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Abstract

The growth of the information and communications technology (ICT) industry over the last couple of decades, spurred by rapid technological changes within the fields of collection and distribution of information, has led to a noticeable shift in the modern policies implemented by governments hosting large IT corporations. Tax benefits, subsidies, labor law exemptions, and government purchases are a few ways how a country can make itself more attractive for new “Google” facilities and support the growth of the ICT sector. However, these policies may not always be beneficial for the economic growth and development of innovative sectors. In this thesis, I study the efficiency of government programs that target ICT firms and show that such support programs may be more suitable for developing countries. A general equilibrium model with innovative goods producers and capital tax provides the theoretical framework and intuition for why the effects of this tax are different for a developed and developing economies. I explicitly show that elasticity of substitution on innovative markets play a significant role for the efficiency if ICT support programs. I employ the IV approach to support my results for the sample of European countries from 1998 until 2020 and study the possible channels for the effect of the support programs on innovation producers. I show that ICT support programs insignificantly increase the growth for developing counties and significantly decrease growth for developed economies.

Keywords: *government, economic growth, IT sector, knowledge flows, Science Parks, taxation*

Abstrakt

Růst odvětví informačních a komunikačních technologií (IKT) v posledních několika desetiletích, poháněný rychlými technologickými změnami ve shromažďování a šíření informací, vedl k významným změnám v moderních politikách implementovaných vládami, které hostí velké IT společnosti. Daňové pobídky, dotace, výjimky z pracovního práva a vládní zakázky jsou jen některé ze způsobů, jak se země může stát atraktivnější pro nové kanceláře Googlu a podpořit růst sektoru IKT. Taková politika však nemusí být vždy prospěšná pro ekonomický růst a rozvoj inovačního sektoru. V této diplomové práce zkoumám efektivitu vládních programů zaměřených na IKT firmy a ukazuji, že takové programy mohou být vhodnější pro rozvojové země. Obecný rovnovážný model s inovativními producenty a kapitálovou daní poskytuje teoretický rámec a intuici, proč se účinky této daně liší pro rozvinuté a rozvojové země. Jasně dokazuji, že elasticita substituce na inovačních trzích hraje významnou roli v účinnosti programů podpory IKT. Pro doložení mých výsledků na vzorku evropských zemí z let 1998 až 2020 používám metodu IV a zkoumám možné kanály vlivu programů podpory na producenty inovací. Ukazuji, že programy podpory IKT nevýznamně zvyšují růst v rozvojových zemích a významně snižují růst v rozvinutých ekonomikách.

Klíčová slova: *vláda, hospodářský růst, IT sektor, toky znalostí, vědecké parky, zdanění*

1 Introduction

The introduction of new information and communication technologies (ICT) in the second part of the 20th century has led to a significant rise in the production capabilities of countries around the globe (Rasel, 2016). Developing countries have gained access to international funding and knowledge flows, thus obtaining more instruments to implement policies that increase the social welfare of citizens. However, the effects of ICT on the global economy have not been unequivocally positive because the increase in transparency and international integration has created an environment conducive to manipulations of the financial markets. The Dot-Com bubble crisis took place in the 2000s because a result of irresponsible use of ICT by investors and the absence of well-defined government regulation of the information sector. The effect of this crisis was drastic because the S&P500 price decreased by a factor of 2 (Basco, 2014). After this crisis, governments began to pay more attention to regulations both on the financial markets and in the ICT sector. These regulations can have ambiguous effects on the productivity and effectiveness of the ICT sector and related spheres. For example, overly aggressive policies can lead to slower growth or underdevelopment of the local innovative firms.

The ICT market is currently one of the fastest-growing markets in terms of gross profits and investment due to its innovativity and flexibility. Research and Development (R&D) departments in international firms are becoming more important for top managers because R&D can be a deciding factor, or a the competitive advantage, in the ”race for knowledge”(Millán et al., 2019). This rapid growth has primarily been driven by the ”fifth technological wave”(FTW) which started in the late 90s and has already changed some traditional markets by introducing improvements in productivity, economic growth, and living conditions. The combination of a flexible business model and high expected benefits is a growth driver for ICT corporations. However, investors may still see the sector as risky to invest in due to the earlier dot-com bubble crisis (Basco, 2014).

The ICT sector affects local economies from several different angles. Firstly, ICT companies are themselves generating profits and producing goods and services that are included in the gross domestic product. The size of this effect can be straightforwardly estimated by the portion of the ICT sector in GDP. For example, the percentage of German GDP generated by the ICT sector was about 5% in 2021, while the agricultural sector accounts for just less than 1% (Eurostat, 2021). Figure 1 shows the aggregated data on value-added by ICT for the EU countries for both manufacturing and service sectors of ICT productions.

In this thesis, I show that the effects of ICT integration on an economy can have a different effect depending on the actions and reactions of the government and the initial characteristics of both the economy in question and the ICT sector. Governments should be extremely cautious when they are considering hosting large IT companies because it can create disturbances in the local economy and boost growth in inequality (Hu, 2007). Ultimately, the ICT sector itself is unarguably the main driver of ongoing innovations. However, some innovations can be harmful to the developing economies if the level of regional development is too low. Therefore, markets may exhibit distortions, including excessive market power, and innovative firms will not function properly. Thus, my hypothesis is that the efficiency of the ICT sector depends on a variety of endogenous and exogenous factors and both governments and researchers should pay attention to these factors when discussing its efficiency.

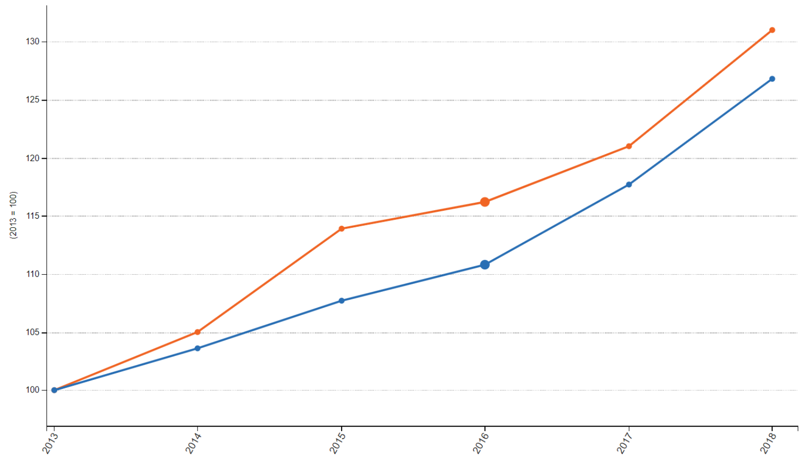

Figure 1: Development of value added by types (blue - manufacturing, orange - services) for ICT sector in EU, 2013-2018. Source: Eurostat (2021)

Innovations as part of ICT are among the main drivers of economic growth (Romer, 1990). Innovations and R&D can have different effects on long- and short-run growth depending on several initial conditions of the economy in question. Assumptions about the economies including the forms of production functions of firms and utility functions of the agents may help researcher to investigate various effects. For example, the studes of elasticity of substitution in the case of the CES production function may help both researchers and policymakers to better understand the effect of taxes on the economy.

The growth of the information technology sector has led to increase in state presence in the Information Technology (IT) sector, although many systems of regulations in IT is still in the initial stages of its development (Mezzanotti & Simcoe, 2019). On the one hand, governments have to use regulations to secure various sides of the market process. In some cases, such regulations create unnatural limitations that slow progress. On the other hand, high net profits and, consequently, high-income taxes can make ICT corporations a good investment option for governments of developing countries, which, through more flexible legislation, may allow IT companies to act in a more risky manner. Therefore, by offering an ICT-friendly environment governments can support the creation of Science Parks, i.e. formations of various IT firms which have offices in one city or city district (for example, Silicon Valley), within national borders. However, the effects of such parks can be ambiguous and depend on various social and economic factors.

Additionally, in response to the growth of the ICT sector governments around the world have started to implement different programs to attract IT firms. These programs are usually focused on various forms of tax breaks for firms and workers. However, the sign and the size of the long-run effects of introducing such programs are different for different regions. For example, European firms were considered less efficient in terms of R&D investments after support programs than American ones (Bloom et al., 2012).

From a more theoretical perspective, the ideas discussed above can be summarised in the following fashion. While taxation of income and capital in the economy usually leads to Pareto inefficient outcomes due to the distortive nature of taxes, unless they are introduced in a lamp-sum fashion, taxation of innovative products may be even more distortive, because innovations affect production in all other sectors through total factor productivity (TFP). Chen et al. (2017) use a general equilibrium model based on Romer (1990) to show that the effects of capital taxation on innovative production differ in both the long- and short-run. In their study they use two different production functions for the innovation firms:

- Linear:

$$\bar{A} = \phi A L_a$$

- Cobb-Douglas:

$$\bar{A} = \phi K_a^{\chi} (AL_a)^{1-\chi}$$

Where K_a, L_a are capital and labor used by the innovative firms, and ϕ is the R&D productivity parameter. The results they obtain are similar for the two specifications and show that increase in capital tax increases optimal growth rate of the economy. However, the plausibility of the chosen functions is questionable. Both linear function and Cobb-Douglas may not be proper representations of reality.

In this thesis, I consider a CES-like production function for the innovation function of new varieties and show that the effects will be different for the short- and long-run:

$$\bar{A} = (K_a^{\frac{\sigma-1}{\sigma}} + L_a^{\frac{\sigma-1}{\sigma}})^{\frac{1}{\frac{\sigma-1}{\sigma}}}$$

This approach can help to better understand the underlying relationships between government and ICT firms and show that the tax increase may not be an efficient way for the government to stimulate efficiency on the innovative markets. The sign of the effect of the tax mainly depends on the elasticity of substitution between factors on the innovative market.

To further support the results of the general equilibrium model I estimate the effects of ICT on the economy, using difference-in-difference and IV approaches, and identify the effects of the introduction of an ICT support effect in the case of European countries over the last two decades. The growth of the ICT sector is an endogenous process that is affected by many geographical, political, and economic factors. I consider only two possible channels of this endogeneity - the number of university graduates with IT-related degrees and the access to the internet in the region. These identification strategies allow me to clean the effect of the ICT on growth and show if it is beneficial for the government to allow the creation of a new Science Park and IT facilities.

From a more granular perspective, the growth in the ICT industry over the last decades has been provoked both by the rapid increase in investment in innovative productions and by the introduction of high-tech advances in third world countries (Taniguchi & Yamada, 2022). It is generally assumed that innovations and economic growth move together in the same direction. However, the effects of the ICT introduction on the region's development can be both positive and negative depending on the initial characteristics of the economy in question. In this thesis, I study how the increase in the size of the ICT sector affects different growth indicators including GDP growth, unemployment rate, the GINI index, and etc.

To sum up, this thesis aims to answer the question of whether the rapid growth of the ICT industry positively affects the economic development in the region where it is introduced and supported by government programs. It is straightforward that innovations are beneficial for the world in general and firms, but the effect may differ for countries with different levels of the initial development of economy and institutions. As a proxy for the development of Science Parks, I use the total number of workers in the innovative firms from Eurostat. As exogenous variables, I use a number of tertiary education graduates. I find that for the pooled IV specifications there is no effect of ICT policy on development, which can be explained by the fact that the effect is different for the developed and developing European countries. Furthermore, ICT industry support significantly decreases the GDP growth and has no effect on the unemployment rate and Gini index for both developed and developing economies. Additionally, the lack of effect may be explained by the low number of observations and the reviewed literature supports its validity. Thus, this thesis contributes to the growing literature on the effects of innovations and sources of economic growth. The study exploits both theoretical and empirical instruments to show that the effects of the ICT development and government programs are noticeable for the economic development.

The rest of the paper is organized in the following way. In chapter 2, I provide relevant literature on the ICT sector, its roles in economic growth, and the main ways in which researchers study innovations in general. I pay attention both to the theoretical frameworks and the empirical results to better fit my study into the scope of the modern literature on innovations. Chapter 3 focuses on the general equilibrium model with innovations and capital taxation. Chapter 4 summarizes the results of the theoretical model and introduces the link between these results and the empirical strategy I employ. I discuss the results for the empirical part in chapter 5 and introduce the main channels which can explain the results from the perspective of economic intuition in chapter 6. Finally, chapter 7 concludes the paper and summarizes all the results.

2 Relevant literature on sources of economic growth and development from ICT

The Information and Communication Technology sector can affect the economy through different channels. For the government to access the effectiveness of each particular channel it may not be enough to study only the microdata. An empirical analysis may be distorted both by technical assumptions and by exogenous errors and patterns in data that are not relevant for the ICT sector. Thus, it may be useful to consider a theoretical model of ICT as the primal approach and empirical studies as a source of supporting materials. In later chapters, I will investigate how authors model different sources of economic growth caused by ICT in the empirical and theoretical literature and what effects are dominating the results. I will use these results to support my claim that the efficiency of the ICT sector depends on the initial characteristics of the economies including the level of development and cooperation of the ICT sector within local markets.

2.1 Efficiency within the ICT sector

One possible source of efficiency is an increase in total factor productivity (TFP). Pieri et al. (2018) assume that the ICT sector affects TFP through the investment-specific channel. Such assumption may be valid for the theoretical model but in reality the effect of ICT is less tractable, because investments in Research and Development (R&D) may not be a perfect proxy for the real investment in innovative production. Furthermore, due to the lack of precise rules for determining the R&D investments, some firms may use it to avoid taxes, thus any statistically significant results from empirical studies may be inconsistent and biased.

To avoid the measurement bias Pieri et al. (2018) build a theoretical model of the ICT sector which affects R&D. They use a stochastic frontier production model to access the effects and empirically check the validity of the results. Their main modeling assumption is that firms use all the resources available and the ICT sector can only help to increase the efficiency of the resources but not their initial allocation. While this assumption seems to be more realistic than the one about investment, this may not be always true for the developing countries where firms tend to misuse the available resources due to lack of technical advancements. Thus, this assumption is not universal due to the endogeneity of the environment where ICT firms operate.

The endogenous effects of the ICT sector on its productivity can differ depending on the county-or region-specific characteristics. Grüner (2009) shows that the same ICT firms have different effects in Europe and USA. The author proposes a theoretical model to account for the possible unobservable components of these puzzling results, but they do not find any statistically significant difference in the effects of ICT.

One of the most convenient ways to explore the efficiency of the ICT sector on innovative firms is to study Science Parks (SP) as they are groups of IT firms that work in the same city or region. The network effects in the case of SP can be a good proxy for effectiveness. However, there are significant disadvantages to such an approach. Firstly, the existence of an SP is itself a distortive factor that may not be exogenous. Secondly, the role of regional characteristics on the effectiveness of SPs may be ambiguous, thus creating additional noise in the estimators. One possible distorter is the existence of a university near the SP. The effects of the university are the main topic of an article by Siegel et al. (2003). However, the assumption that university SPs are the main driver of the economic growth may be realistic only for developed countries where the quality of education system allows for industries to access the benefits of research centers, Siegel et al. (2003) find evidence that the strength of the ICT effects depends on the distance to the closest university. This result supports the assumption that the effectiveness of the ICT sector may depend on the characteristics of local infrastructure.

Finally, López-Pueyo & Mancebón (2010) show that ICT can affect productivity directly through an increase in labor productivity in the ICT sector without capital intensification. This theoretical study combines a theoretical approach with non-parametric estimation, thus avoiding the trap of contradicting assumptions. Their results are similar to those from the article by Vásquez-Urriago et al. (2016) who empirically study the same effects on the Spanish data about large Science Parks. These two complementary analyses support the common assumption that the efficiency of ICT comes from cooperation within the ICT sector and has the most noticeable effect on human resources departments including boards of directors and high-level managerial crews. The main modeling assumptions behind these results are exogeneity and availability information for all the ICT firms. This assumption is realistic and holds for the majority of modern economies. Thus, these results support my claim that the initial characteristics of the local economy are the major factors affecting the efficiency of the ICT sector. I will focus more on the modelling assumptions of the paper by Vásquez-Urriago et al. (2016) in the next sections.

2.2 Efficiency with the non-ICT sectors

The ICT sector can cause economic growth by affecting other sectors including banking and sales. The interrelations between different sectors within the modern market economy make it possible to achieve a high level of cooperation between seemingly unrelated spheres. This cooperation leads to increases in production and economic efficiency. However, an increase in the connections between sectors can have its disadvantages because bigger corporations can gain more market power and create a suitable environment for the monopoly to replace free markets. Such negative effects of the introduction of ICT can be seen in several developing countries including China and India Zheng & Zhang (2021).

Drozd & Serrano-Padial (2017) theoretically study another possible positive spillover of ICT. They extensively study the effects of ICT introduction in banking, i.e. implementation of adaptive technologies which can lower the risk of default. They use a simple general equilibrium model to support their hypothesis. Authors focus fully on the theoretical modeling which makes it less applicable for the real-world data. However, their model produces stable and valid results in terms of simulations and comparative statics; the assumptions they impose are strong and sometimes may not be consistent with reality. This paper will be later discussed in more details and compared with the existing literature in the next sections.

Brynjolfsson & McElheran (2016) study ICT sector effects from a different perspective focusing more on the manufacturing sector of the USA. They do not consider ICT firms directly but discuss how the implementation of data-driven decision-making and data analysis can affect the results of firms that are not innovative. This study coincides with ideas from Bloom et al. (2012) who investigate the effects of an increase in labor productivity on the firm's performance outside of the ICT sector. While both these two articles are fully empirical, it is worth mentioning that their underlying assumptions arise from Solow (1956) which is one of the core theoretical articles about growth and development in economics.

2.3 Efficiency from government perspective

The government may care about the efficiency of ICT because it can affect GDP growth possibilities directly and through other sectors. Rasel (2016) examines the effects on small and large businesses. He compares the effects of ICT and R&D development on firms of different sizes and shows that the effect of innovations has uniform distribution when disregarding the initial characteristics of the firms. These results may be interesting from the governmental perspective as in the modern economy the policies mainly target small independent businesses which are less likely to have access to global knowledge and innovation markets. Moreover, the effect of innovations is more noticeable for decentralized small companies and not for the big manufacturing agglomerates. However, the results obtained by Rasel (2016) are significant and robust, they may be mostly driven by the country-specific characteristics of their data because Germany has a strong economy, which ensures competitiveness and does not allow oligopolies or other forms of market power according to author.

One possible drawback of the introduction of ICT to the local environment is the growth of inequality in the late stages of development. Hu (2007) studies the effect of Sciency Parks on local Chinese development and shows that while the effects are positive in the short-run in the long-run the localities can experience growth in inflation and inequality if the distribution of innovative and non-innovative firms is shifted towards the non-innovative sector.

The possibility of crisis is a major fear of any government because the effect of the crisis can spread from the economic sphere to other spheres including politics. IT companies that are working within the innovative industry may be a possible source of new global and local economic downfalls. Basco (2014) studies the theoretical model of the Dot-Com bubble crisis using several assumptions about both countries and the ICT sector itself which was the initial reason for the recession. The author finds evidence that the effect of crisis depends on both the size of the exogenous shock and the initial characteristics of the economy, thus supporting my claim that country-specific traits of the economy matter for the innovations to be non-harmful.

Finally, Shin & Park (2007) summarize the possible gains for the government from ICT. They study the case of the South Korean ICT sector which provides economic growth by exporting innovations and increases GPD both through net exports and external investments. As the main focus of the Korean IT firms is not the production of goods but the provision of services, their efficiency does not depend on the capital investment and the current state of the economy. Thus, they are not essential for the ICT sector or innovations but still are profitable for the government. This result shows that in some cases initial characteristics of the economy may be irrelevant for efficiency.

2.4 Regulations and taxation on the ICT markets

The literature about the taxation of the innovative firms mostly consists of the empirical studies on firm-level data (Zheng & Zhang, 2021; Liu et al., 2021). By studying the effect of the tax reduction on the different firm characteristics including levels of production and net profits authors show that tax reduction increase firms' productivity, thus, providing growth possibilities for the economy in general. However, such studies may be useful from a policy recommendation perspective, they cannot provide deep economic intuition behind the obtained results.

Another cluster of studies related to the efficiency of the R&D and the innovative firms considers a theoretical behavioral model with boundedly rational agents. For example, Dragone et al. (2021) study the effect of the emission taxation and R&D effort on pollution in the framework of the differential Cournot game. One of their main findings is that the Pareto optimal equilibrium with the usage of the green/innovative technologies may be achieved both by setting the appropriate tax and by regulating the market access. The same approach was adopted by Feichtinger et al. (2016) to show that inverted-U-shaped investment curves which are necessary for the existence of the Pareto optimal allocation of innovations arise not solely from the specification of the production function but also the regulatory measures. These results can indicate that government intervention may be crucial for the innovations to be fully efficient in some cases.

The fully theoretical approach in this field is also presented by the articles which use classical Ramsey and Mirrlees approaches to study different effects of the innovations and R&D on the economic growth possibilities. Ferraro et al. (2020) use the DSGE model of innovation-led growth to show how the endogeneity generated by the model can explain the duration of tax shock effects. In their model, authors distinguish in their model two types of innovations to better fit the reality:

product innovations and quality-improving innovations. They use post-war U.S data to estimate the model and show that long-run growth is not affected by labor income taxes but is affected by the time-varying tax rates on individual and corporate incomes.

The article by Chen et al. (2017) provides another view on the effect of the innovations. Authors model innovations as growth in the variety of inputs for the production of the consumption goods. They use different specifications for the production function of R&D firm to show how the shifting in taxation mechanism can affect long-run economic growth. However, in their research, they consider only the two most common specifications: linear production function with only one factor (labor) and Cobb-Douglas production function with two factors (labor and capital). The main result of the paper is that the capital tax may lead to an increase of the steady state growth rate of the economy. The effect goes thought the tax-shifting channel, i.e switch from the labor taxation to the capital taxation. Authors also find that the signs of effects differ for the short- and long-run. Using the US data they show that in short-run increase of capital tax lead to the decrease in growth rate, while in the long-run the effect is opposite. While Cobb-Douglas may give more robust results and provide answers to a wider range of questions than the linear one, its plausibility for the description of real-world relationship may be doubtful (Aiyar & Dalgaard, 2009). Furthermore, Gilbert et al. (2018) states that innovation requires a CES-like production function in the case of the oligopolistic market structure. The constant elasticity of substitution production function also can help to determine the role of elasticity substitution in the growth path with different taxation mechanisms.

2.5 Empirical vs theoretical approaches

In this section, I discuss in more detail two papers that study the effect of the ICT introduction on economic performance and compare the main modeling assumptions and approaches the authors use. For the comparison, I focus mainly on the two which estimate the effect of the ICT sector on non-ICT sectors. The first paper is by Drozd & Serrano-Padial (2017) uses a more theoretical approach, while the second one by Vásquez-Urriago et al. (2016) uses a purely empirical strategy. The main goal of this section is to show the complementarity of these two approaches in the case of the ICT industry.

The main difference in assumptions that distinguish the theoretical and empirical approaches is the assumption about the endogeneity of the ICT effect on the economy. While the empirical papers try to deal with the possible unobservable country- and industry-specific effects by the introduction of various controls, the theoretical ones pay more attention to this problem and develop more sophisticated links between the ICT sector and productivity in the economy in general. However, the sophistication of the latter approaches comes at the price of the loss in the generality of the results. Thus, the existing trade-off between the two approaches is between tractability/interpretability and universality.

An article by Wang (2018) shows how different policies affect the effectiveness of the ICT sector and local economy by comparing firms in Singapore and Hong Kong firms. The author shows that aggressive policy to attract big multinational companies and their R&D departments in Singapore in the late 80s failed to achieve any positive results and harmed the economy and its ICT sector. The more ”humble” approach, which Singapore has been using since the 90s, focuses on developing local IT sector firms because it helps to increase the productivity of local firms and the innovative sector in general without becoming dependent on external R&D departments. While Singapore represents a more active approach to ICT policies, Hong Kong's policies are more neutral and do not force rapid growth in the ICT sector. Using the Difference-in-Difference approach Wang (2018) argues that Hong Kong's neutrality and ignoring of the ICT sector may be as harmful as the aggressive policy. These results support my claim that governments should be extremely cautious when they are dealing with the ICT sector because both aggressive and passive actions can lead to a recession.

The ICT sector can affect the economy through a variety of different channels including co-operation within the ICT sector and intersectoral cooperation between IT firms and non-IT firms. The effects of such cooperation may be both positive and negative depending on the different initial characteristics of the economies and their level of development. Thus, the question of efficiency in the case of innovations should be considered carefully using different sets of assumptions to avoid negative consequences and incorrect policy recommendations. Both theoretical and empirical studies support my claim that the ICT sector may have an ambiguous effect on different countries.

One of the main implications of the results above is that any aggressive policy decision about the ICT sector can lead to negative consequences for the economy. The examples of Singapore and Hong Kong show that to sustain the growth of the local ICT sector government has to implement both active and non-aggressive programs which should be specific to the local environment. Furthermore, the effects of the policies may have not only short-run nature but also affect the long-run equilibrium growth.

To sum up, the importance of the ICT sector in modern market economies is an unarguable fact. Thus, it is crucial both for governments and firms to understand how ICT can affect production and growth under different assumptions about the real state of the economy. This idea supports my claim that assumptions play a significant role in determining whether the ICT sector will be efficient or will cause a crisis that may harm all the spheres of the local economy.

For example, Vásquez-Urriago et al. (2016) use survey data to establish the links between innovation initiatives between companies that belong to the same Science Park. They argue that firms, that are close to each other in a purely geographical sense and participate in one Science Park, have a higher level of cooperation than those companies that participate in different Science Parks.

The Vásquez-Urriago et al. (2016) use all the available data about Spanish ICT sectors collected from a survey by the Spanish Institute of Statistics (INE). The large sample and number of parameters allow them to check a wide range of hypotheses about Science Parks and IT firms including the size of the cooperation bonuses and spatial effects of the facility locations. In comparison with previous studies in this area (Westhead & Storey (1995)) this article extents both the number of the studied facilities (Science Parks) and the number of observations which makes the research one of the most deliberate in terms of robustness, efficiency, and reliability of the results.

Vásquez-Urriago et al. (2016) estimate their results via the Average Treatment Effect (ATE) technique which is a common instrument for analysis of changes between two groups with similar initial characteristics. The choice of this technique affects both the estimation procedure and economic interpretation of the results because ATE has technical issues when data is highly heterogeneous and heterogeneity is one of the main characteristics of the IT sector. Vásquez-Urriago et al. (2016) estimate several models including regression for the location in Science Park and regression for the diversity of effects the cooperation can create within forms of the contractual relationship. Additionally, they mention that the problem of endogeneity is present in their models and the tests reject the hypothesis of exogeneity, this result follows the economic intuition because characteristics of the IT firms discussed in the article, including age, size, and e.t.c., may not be independent of each other. Vásquez-Urriago et al. (2016) provide an extensive study of the effect of Science and Technical Parks (STP) on the productivity and efficiency of ICT. They use Spanish data on the STPs and the way they encourage cooperation between firms within the IT industry and between IT and other industries. Vásquez-Urriago et al. (2016) divide firms into two groups: park and non-park firms. However, the assumption about exogeneity of new STP location, which authors make, may not be realistic, it allows them to estimate the Average Treatment Effect of STP introduction using propensity score. Authors find that the effect of Science Park creation is positive for all the firms both inside and outside of the park.

Finally, Vásquez-Urriago et al. (2016) come to a conclusion that collusion between firms within the same Science Park is affecting cooperation in a wide range of aspects including length of contracts and flexibility of terms and conditions. Furthermore, they also account for the endogeneity and selection biases by introducing a set of econometric instruments. Although the amplitudes of the estimated results are not large, their significance both in terms of statistics and economic intuition shows the reliability and robustness of the results.

Drozd & Serrano-Padial (2017) use a purely theoretical approach to estimate the effects of ICT firms on debt collection. They study how the growth of advanced scoring methods provided by IT firms can change the profits of financial institutions by lowering unnecessary risks. The article provides several explanations for the importance of using IT in the banking sphere.

Drozd & Serrano-Padial (2017) consider information technologies provided by the ICT sector as the mechanism which can improve the quality of signal financial institutions are receiving from potential debtors. The IT sphere plays the role of a ”perfect observer” who can determine the level of expected risk associated with each particular debtor. Drozd & Serrano-Padial (2017) build the general equilibrium model with an idiosyncratic financial distress shock and ability to default after the realizations of shock and choice of the consumption level. Both lenders (bank) and debtor (household or agent) are maximizing their utilities which positively depend on the money as a tangible asset. For the lender, it is profitable to make the debtor repay, and for the debtor, it is usually preferable to default even in the presence of the punishment. Authors introduce IT as state verification technology that helps banks to recollect unpaid debt and increase the probability of successful punishment.

Drozd & Serrano-Padial (2017) use American data from the beginning of the 2000s to calibrate their model and show that the introduction of the IT sector increases the debt repayment rate and decreases the number of defaults. Furthermore, they show that there exists a threshold for the profitability of IT usage. The comparative statics analysis allows checking the main hypothesis about the IT industry in the financial industry.

Both articles discuss the effect of IT companies on the various aspects of the modern economy. However, the two approaches are different both in their technical part and economic intuition. While Drozd & Serrano-Padial (2017) study the effects of ICT growth on non-IT firms, financial institutions in particular, Vásquez-Urriago et al. (2016) investigate the interrelationship between firms within the ICT sector. The assumption these articles share is the necessity of government intervention either in a form of initial investment and government purchases or in a form of an enforcer who can make the different sides of the IT market follow the established rules. Furthermore, Qu et al. (2013) and Nathan & Rosso (2015) come to the same conclusions using data for the Chinese and British economies which makes such assumptions more reliable and universal for the ICT sector in general.

Although similarities between models may be difficult to notice because of the nature of the two studies, there are certain general assumptions that authors commonly use in papers about ICT.

While the empirical approach used by Vásquez-Urriago et al. (2016) is more practical and can be used in policy-making directly without further adjustments, the theoretical one applied by Drozd & Serrano-Padial (2017) has more deliberate and complicated forms. The universality of the theoretical approach allows it to be transformed to serve several purposes including assessing the efficiency of the cooperation between the IT sector and various non-IT sectors. However, the base assumptions made by both papers are partially driven by the nature of the chosen instruments they can still be compared in the light of their efficiency and adequacy.

Both models share is exogeneity of the IT sector effects. For instance, Vásquez-Urriago et al. (2016) assume that the location of Science Parks in Spain has random nature, i.e. is not affected by economic activities and internal factors. While for the empirical paper such an assumption can be justified by purely statistical reasons, in the case of general equilibrium modeling exogeneity may not be a proper representation of the real business cycle processes. Despite the fact mentioned above, Drozd & Serrano-Padial (2017) assume that technical progress created by the ICT sector appears in the economy by chance and has no source which can be modeled directly. Although Drozd & Serrano-Padial (2017) list this problem as one of the possible limitations, such an assumption still may affect the reliability of both comparative statics analysis and calibration results.

Furthermore, Vásquez-Urriago et al. (2016) use assumption about the immobility of IT firms across different Science Parks which arises from the nature of the data they use. Similarly, Drozd & Serrano-Padial (2017) introduce an external limit for debt renegotiation or bankruptcy which affects the IT sphere indirectly through capital-investment channels. Additionally, Drozd & Serrano-Padial (2017) assume that prices on the market follow the Bertrand competition scheme and that finance charges are non-distortionary and do not affect the interest rates, probabilities of detection, and some other variables which characterize the economy. These two assumptions allow them to avoid unnecessary derivations without loss of generality.

To sum up, the computational assumptions both Vásquez-Urriago et al. (2016) and Drozd & Serrano-Padial (2017) use may be only partially justified by the economic intuition and seem to be legit in the case of analysis of big samples data. Furthermore, the theoretical assumptions do not contradict reality. Both reviewed articles discuss the topic of IT sector integration into the modern economy. Although the scopes of the studies are incomparable due to their nature, i.e. empirical approach vs. the theoretical one, the results Vásquez-Urriago et al. (2016) provide may have more economical implications and help with policymaking connected to the IT sector. Drozd & Serrano-Padial (2017) develop a model which establishes the framework for future research and produces some important insights which are less practical but can help in understanding the eternal relationship between IT and non-IT sectors better. Furthermore, Vásquez-Urriago et al. (2016) introduce a wide range of various hypotheses about the relationship between IT firms, Drozd & Serrano-Padial (2017) investigate only one particular idea about information technologies in banking, but do it from different angles.

The results of both articles confirm the well-known fact that the introduction of information technologies increases the productivity and revenues of firms involved in the innovation process. Furthermore, the authors explicitly show that these positive effects are noticeable not only for IT firms themselves but also for the non-IT sectors like banking. Disregarding the initial technical assumptions the final results are supporting the idea of the necessity of IT integration.

Vásquez-Urriago et al. (2016) and Drozd & Serrano-Padial (2017) show that ICT corporations and innovation affect the relationships within financial sectors and the IT sector in various ways. While they observe significant positive changes associated with the growth of information technologies in studied sectors, in the theoretical model estimations are less reliable in terms of robustness and assumptions because Drozd & Serrano-Padial (2017) use exogeneity assumption which is not always justified by the economic theory. Vásquez-Urriago et al. (2016) limit their research by taking into account only Spanish ICT firms and focusing on differences of effects between members of Science Parks and non-members, however, due to the large sample such division does not cause problems with inference.

Furthermore, both papers discuss the effect of IT firms on the economical relationship within the modern economy. The assumption that governments have to support Science Park and ICT firms developed by Drozd & Serrano-Padial (2017) is partially supported by Spanish data. Thus, the results obtained in the studied articles complement each other, which supports the idea that in the evaluation of the ICT environment it is essential to simultaneously use theoretical and empirical approaches to achieve higher validity of the results. Further research in this area may help determine if the same effects are valid for other markets within different economies.

The effects of the ICT growth in the country empirically are studied both on national and firm levels. While the second approach is more common in modern literature due to access to high-quality microdata, the first one still can help in answering questions about the efficiency of ICT. Usage of cross-country analysis may provide estimations of universal trends and consequences of the direct policy intervention in the case of the IT industry because for different regions the effects can differ drastically.

The study of European firms and US multinationals provides evidence that there are some underlying problems in Europe with the usage of innovations (Bloom et al., 2012). These underlying problems can lead to the ICT sector and R&D being inefficient and sometimes even harmful to the local economies. Bloom et al. (2012) empirically show using panel data analysis that poor management is the crucial difference that makes European ICT firms less efficient.

Nathan & Rosso (2015) conduct a study similar to Vásquez-Urriago et al. (2016) for the UK innovative firms to show the effects of ICT on the employment rates. The authors do not try to draw conclusions about the causal relationship between ICT and development but try to make a proper description of the ICT sector.

While in the majority of studies authors use firm-level data to access the effects of the increase in innovation-related investments and government subsidies to the ICT firms for specified European countries, they do not compare the results for different countries. For example, Bronzini & Piselli (2016) use the case of the Italian regional RD subsidy program and difference-in-difference and 2SLS approaches. They show that the subsidies indeed increase the efficiency of the ICT industry due to their positive effects on the small innovative firms. Furthermore, Mulier & Samarin (2021) obtain similar results, however, they also state that the result is highly affected by the initial characteristics of the ICT sector including the level of competitiveness and knowledge exchange intensity.

The wider approach with cross-country data is less present in the literature due to the complexity of data collection and the reliability of aggregated indicators. However, the issues mentioned above may affect the results, studying the country-level effects may provide insights into the general trends of innovations (Hu, 2007). For example, Hardy & Sever (2021) study the effects of the global financial crisis on the ICT industry and its efficiency. The focus on banking crises allows authors to estimate long-run consequences for the innovations after the crash of financial institutions. Hardy & Sever (2021) use data from 32 countries and 52 financial crises from 1976–2006 and shows that while the banking crisis may affect investment in innovation, the quality of the innovations remains stable. Another study using data from several countries is an article by Bodas Freitas et al. (2017). Authors consider Norway, Italy, and France to study the effects of R&D tax credits to show that the effectiveness of ICT policy depends on the initial characteristics of the economy. One of their additional results is that industries that have stronger connections to ICT tend to gain more from the innovation-supporting policies, thus, indirectly strengthening the effects of ICT on GDP growth.

As the ICT industry may consist of innovative firms with different specializations, the sizes and directions of the effects on development may differ. Kim et al. (2021) show the difference between the wired and wireless mobile ICT effects on regional growth. Authors show that while for the regions with wired connection the effects of ICT are insignificant for both developed and developing economies, for the regions with wireless mobile infrastructures innovations significantly increase GDP.

An example of the negative effects of innovation is presented by the paper by Wang (2018) about Singapore and Hong Kong discussed earlier in this section. The author shows that an aggressive approach that focuses on external R&D investments leads to the degradation of the local innovative firms. The development of the local R&D departments according to Wang (2018) used by the Singaporean government leads to an increase both in the ICT sector and all the related spheres.

Similar to Wang (2018) Qu et al. (2013) try to estimate the effects of the external innovations affecting the development of local R&D in the hosting county. Authors use Chinese data on innovative and non-innovative firms to show that the positive spillover of multinational firms setting R&D department in the region disappears if the distance between department and headquarters is significantly long. This result can partially explain the decrease in local innovation production in Singapore in the late 80s which was considered in the work by Wang (2018).

To sum up, the literature about ICT and its effects on development mostly focuses on the relationship between firms and sectors and only a few articles compare these effects on the country- and firm- levels. However, the microdata provides insights into how innovative firms can help non-innovative, and the evaluation of cross-country effects may answer the question about the necessary conditions for the efficiency of the ICT sector for the region. The combination of the theoretical and empirical approaches may help to identify the channels of the effects in more robust ways. The studies by Drozd & Serrano-Padial (2017) and Vásquez-Urriago et al. (2016) show that the persistent effect of the ICT integration is beneficial for both ICT and non-ICT firms. These two articles help to create a full picture of the studied effects.

3 General equilibrium model of taxation on the ICT markets

3.1 Model Setup

The model will use the setting from Romer (1990) with continuous-time and taxes on labor and capital. I will closely follow Chen et al. (2017) in the notations and derivations. Thus, the model will have a household, two firms producing intermediate and final goods, innovation producing firms, and government. The main difference will be for the derivations related to the production of the innovative firms.

3.1.1 The household

In the economy there is a representative agent who maximizes all his future utilities:

$$U = \int_0^\infty e^{-\rho t}(ln(C_t) + \theta\frac{(1-L_t)^{1-\eta}}{1-\eta})dt$$

where C_t is consumption, L_t is number of hours worked, and $\rho > 0$ is the discounting factor.

The budget constraint for the HH is given by:

$$K_{t+1} + a_{t+1} + C_t + Z_t = ra_t + (1-\tau_K)r_K K_t + (1-\tau_L)wL_t,$$

where K_t is capital stock, r is interest rate, r_K is the capital interest rate with non-arbitrage condition $r = (1-\tau_K)r_K$, and Z is either lamp-sum tax or transfer.

3.1.2 The final good producer

Production of the final goods is done according to the following Cobb-Douglas function using labor and intermediate inputs:

$$Y_t = L_t^{Y\,1-\alpha} \int_0^A x_{it}^{\alpha} di$$

Where A is the variety of the intermediate goods.

Final goods producers act in a perfectly competitive environment with the price of the intermediate good i being p_i and price of labor is equal to w. The price of the final good is a numeraire and set equal to 1.

3.1.3 The intermediate good producer

Firms producing intermediate goods are monopolists with production function being:

$$x_{it} = k_{it}$$

Thus, they solve following maximization problem:

$$\pi_i = p_i x_i - r_K k_i$$
$$K_t^{int} = \int_0^{A_t} k_{it} di$$

3.1.4 The innovation producer

New variety is produced from both labor and capital using CES production function:

$$A_{t+1} = ((K_t^A)^{\frac{\sigma-1}{\sigma}} + (A_t L_t^A)^{\frac{\sigma-1}{\sigma}})^{\frac{1}{\frac{\sigma-1}{\sigma}}}$$

Where σ is elasticity of substitution and $K_t = K_t^A + A_t k_{it}$ and $K_t^A.L_t^A$ are capital and labor used by R&D firms. Furthermore, I can directly write down growth rate of innovations in the economy from the production function:

$$\gamma_A = \frac{A_{t+1}}{A_t} = ((\frac{K_t^A}{A_t})^{\frac{\sigma-1}{\sigma}} + (L_t^A)^{\frac{\sigma-1}{\sigma}})^{\frac{1}{\frac{\sigma-1}{\sigma}}}$$

Thus, the growth rate of the variety depends positively on the number of workers employed in the innovative sector and the value of the elasticity of substitution.

3.1.5 Government

Every period government has to satisfy its budget constraint:

$$\tau_K r_K K_t + \tau_L w L_t + Z_t = G_t$$

Where $G_t = \beta Y_t$, i.e. government spending is a constant fraction of the final output.

3.1.6 Definition of equilibrium

The decentralized equilibrium consists of $\{C_t, K_t, A_t, Y_t, L_t, L_{Yt}, L_A, x_t, G_t\}_{t=0}^{\infty}$, prices $\{w, r, r_K, p_i, V\}_{t=0}^{\infty}$ given taxes and transfers $\{\tau_K, \tau_L, Z\}$ so that they satisfy following conditions:

- $\{C_t, K_t, L_t\}_{t=0}^{\infty}$ solves HH problem;
- $\{L_t^Y, x_t\}_{t=0}^{\infty}$ solves the problem of final good producers;
- $\{k_i, p_i\}_{t=0}^{\infty} \forall i \in [0, A_t]$ maximizes profit of intermediate good producer;
- $\{L_t^A, K_t^A\}_{t=0}^{\infty}$ solves the problem of R&D firms;
- the markets clear:
  - Goods: $C_t + K_{t+1} + G_t = Y_t$
  - Capital: $K_t = Ak_{it} + K_t^A$
  - Labor: $L_t = L_t^A + L_t^Y$
- Government budget is balanced in any period: $\tau_K r_K K_t + \tau_L w L_t + Z = G_t$

3.2 Solution for the model and discussion of the results

3.2.1 Derivations of equilibrium conditions

From the HH problem I can get:

$$\frac{C_{t+1}}{C_t} = (1-\tau_K)r_K - \rho$$

$$\theta C_t = (1-\tau_L)w$$

From the problem of the final good producer demands for labor and intermediate goods I can derive:

$$L_Y = (1-\alpha)\frac{Y}{w}$$

$$x_i = L_Y(\frac{\alpha}{p_i})^{\frac{1}{1-\alpha}}$$

From the fact that intermediate good producers are monopolists I can obtain:

$$p_i = \frac{r_K}{\alpha}$$

$$\pi_i = \frac{(1-\alpha)\alpha Y}{A} = \pi$$

From the innovation producing firm problem and new definition of variety value with no arbitrage condition: $rV_t = \pi + V_{t+1}$, where V is value of the monopolistic intermediate firm. The R&D firms profit:

$$\pi^{R\&D} = A_{t+1}V_t - wL_t^A - r_K K_t^A = ((K_t^A)^{\frac{\sigma-1}{\sigma}} + (A_t L_t^A)^{\frac{\sigma-1}{\sigma}})^{\frac{1}{\frac{\sigma-1}{\sigma}}} V_t - wL_t^A - r_K K_t^A$$

Taking FOCs:

$$\frac{K_t^{A\frac{\sigma-1}{\sigma}-1}}{(K_t^A)^{\frac{\sigma-1}{\sigma}}+(A_tL_t^A)^{\frac{\sigma-1}{\sigma}}}A_{t+1}V = r_K = K_t^{A\frac{\sigma-1}{\sigma}-1}A_{t+1}^{1-\frac{\sigma-1}{\sigma}}V$$
$$\frac{L_t^{A\frac{\sigma-1}{\sigma}-1}}{(K_t^A)^{\frac{\sigma-1}{\sigma}}+(A_tL_t^A)^{\frac{\sigma-1}{\sigma}}}A_{t+1}V = w = L_t^{A\frac{\sigma-1}{\sigma}-1}A_{t+1}^{1-\frac{\sigma-1}{\sigma}}V$$

Thus, unlike the Cobb-Douglas case discussed by Chen et al. (2017) the rate of growth will generally not have the same direction for innovative capital and variety as:

$$\frac{A_{t+2}}{A_{t+1}} = (\frac{K_{t+1}^A}{K_t^A})^{1-\frac{\sigma-1}{\sigma}}$$

Under the universal assumption of $\sigma > 0$ the directions will coincide so the growth of capital and innovations will have the same signs. This result hints that the innovations may be less important for the countries where the capital growth is the highest among other factors of production.

Now combining the equation above with the budget constraint for the government, no-arbitrage and market clearing conditions I will have 17 equations and 17 unknowns:

$$\{C; L; A; K_A, k_i; L_Y; x; r_K; \pi; r; G; \tau_L; Y; \lambda; L_A; V; w\}$$

. A lump-sum tax is not a realistic assumption in further derivations I will set $Z_t = 0$ and will consider only shifting from the labor tax to income tax. Firstly, I can rewrite government budget constraints to find the optimal path. For the growth to be optimal I have to assume that:

$$(\frac{K_{t+1}^A}{K_t^A})^{\frac{1}{\sigma}} = \frac{Y_{t+1}}{Y_t} = \frac{C_{t+1}}{C_t} = \frac{A_{t+1}}{A_t} = \gamma$$

As all the growth rates are the same and the relationship between growth rate and labor on the growth rate of variety is known from the production function of R&D firms, it is enough to derive the effect of switch from the labor tax to the capital tax on the total amount of labor in the economy. I am assuming that labor tax is endogenous in this case and depends on the capital tax, thus, I can calculate the effect of capital tax on labor growth. Firstly, from the intermediate good producer I can get the following system by dropping the time index for the simplicity of notations:

$$r_K \int_0^A k_i di = \alpha^2 Y$$
$$L_y = (1-\alpha)\frac{Y}{w}$$
$$\tau_K r_K K + \tau_L w L = \beta x^\alpha L_y^{1-\alpha}$$
$$Y = A^{1-\alpha}(\int_0^A k_i di)^\alpha L_y^{1-\alpha}$$

So I can derive the condition for the relationship between capital and labor tax:

$$\tau_L = \frac{\beta x^\alpha ((1-\alpha)(\frac{A^{1-\alpha}(\int_0^A k_i di)^\alpha L_y^{1-\alpha}}{w}))^{1-\alpha} - \tau_k r_k K}{wL}$$

As in this case, the capital of the intermediate good is not equal to the total used capital, expression cannot be simplified further. Now I can derive the expression for the optimal total labor from labor market clearing, demands, and the results above. The solution for the quadratic equation will be different from one in Chen et al. (2017):

$$L = \frac{\frac{A_{t+1}^{1-\frac{\sigma-1}{\sigma}}}{\rho\theta} + \sqrt{(\frac{A_{t+1}^{1-\frac{\sigma-1}{\sigma}}}{\rho\theta})^2 - 4\frac{\Phi(\tau_K)A_{t+1}^{1-\frac{\sigma-1}{\sigma}}}{(1-\Phi(\tau_K))\theta}}}{\frac{2A_{t+1}^{1-\frac{\sigma-1}{\sigma}}}{\rho}} = \frac{\frac{1}{\rho\theta} + \sqrt{(\frac{1}{\rho\theta})^2 - 4\frac{\Phi(\tau_K)}{(1-\Phi(\tau_K))A_{t+1}^{1-\frac{\sigma-1}{\sigma}}\theta}}}{\frac{2}{\rho}}$$

Where $\Phi(\tau_K) = \frac{\beta - \alpha^2 \tau_K}{1-\alpha^2}$. So the derivative is:

$$\frac{\partial L}{\partial \tau_K} = 4\frac{\sigma - 1}{\sigma} \frac{\frac{\Phi'(\tau_K)(1-\Phi(\tau_K))A_{t+1}^{1-\frac{\sigma-1}{\sigma}}\theta - \Phi(\tau_K)(1-\Phi(\tau_K))A_{t+1}^{1-\frac{\sigma-1}{\sigma}}\theta + \Phi(\tau_K)\Phi'(\tau_K)A_{t+1}^{1-\frac{\sigma-1}{\sigma}}\theta}{((1-\Phi(\tau_K))A_{t+1}^{1-\frac{\sigma-1}{\sigma}}\theta)^2}}{\sqrt{(\frac{1}{\rho\theta})^2 - 4\frac{\Phi(\tau_K)}{(1-\Phi(\tau_K))A_{t+1}^{1-\frac{\sigma-1}{\sigma}}\theta}\frac{2}{\rho}}}$$

This expression depends on the substitution parameter and the level of innovation production. Under the assumption that growth rates are same and equal to γ, the effect of tax is not as unambiguous as in cases of linear and Cobb-Douglas functions. This results shows that when more complicated function for the production of R&D firms is considered the effect of ICT sector on the economy becomes more sensitive to the economy characteristics which supports the ideas seen in the empirical literature. The economic intuition behind this result may be that if the elasticity of substitution is sufficiently high for the producers of innovations there is no difference between labor and capital, thus, tax on any of the inputs may be easily compensated using another input and no tax other than zero will be optimal in the equilibrium. Thus, when elasticity of substitution capital and labor is low and factors can not be substituted, the effect of taxes is more distorting. These distortions affect both the final (through aggregation of intermediate goods) and innovation goods producers decreasing the growth rate of the economy. Therefore, government have to decrease the income tax to save the economy from stagnation. This decrease in taxes may be viewed as both the direct change in the tax policy and the tax break for some innovative firms.

3.2.2 Numerical solutions and analysis

I will adopt the values for the exogenous parameters from Chen et al. (2017) except for the value for elasticity of substitution σ which is taken from Klump et al. (2012). The study by Klump et al.

(2012) considers different values for the substitution parameters and shows that the most realistic ones are either 0.57 or 1.45. I use both of them to calculate the optimal values and the responses of the optimal growth rate to the changes in capital tax.

Parameter	ρ	α	β	τ_K	θ	σ
Value	0.04	0.40	0.20	0.29	1.047	0.57 / 1.45

Table 1: Values for the exogenous parameters

The resulting graphs show how the optimal growth differs with various levels of capital tax and two different levels for the elasticity of substitution. The horizontal line in orange represents the optimal growth rate with optimal taxation and the line in blue shows the growth rates with exogenously given capital tax.

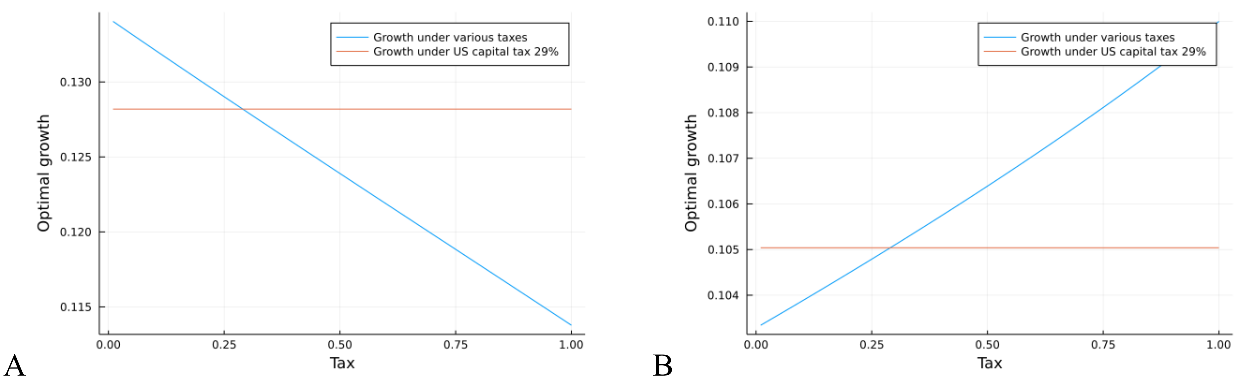

Figure 2: Effect of taxes on growth rates under different elasticities of substitution

The benchmark value on the graph which is represented by the blue line is the US combined capital tax which is equal to 29%. This value is a representative benchmark because all the other values were calibrated fro the US economy. Furthermore, this value of tax is lower than for the rest of OECD countries which make this choice more conservative and representative for the developed economies in general OECD (2022) The panel A shows the case when the elasticity of substitution is small the increase of capital tax will lead to the decrease in the growth rate for the economy. For Panel B an arbitrary large value for the elasticity is chosen and the graph looks similar to the one obtained by Chen et al. (2017). This case is consistent with the result that increase in the capital tax increases growth rate. However, the size of the effect in panel B is relatively smaller than the one in panel A. These results also support the ideas from the analytical solution showing that it is profitable for the government to intervene only if there is high elasticity of substitution on the R&D market.

4 Elasticity of substitution and economic growth

In this section, I provide the intuition for the results obtained from the theoretical model and create a link between these results and the empirical identification strategy I use in the next sections. This section aims to show that the results from the general equilibrium model may be useful for empirical analysis. The section also provides a general overview of the relevant literature and results related to the role of elasticity of substitution for economic growth.

In the theoretical model studied above the main driver of economic growth is the population or labor growth. In my simplified setting, this growth may be a proxy for both the growth of hours worked and the growth of the quality of the labor. While for the first definition, the logic of the effect is straightforward, for the second one there is a deeper connection with the real world. The sign of the effect in both cases will depend on the elasticity of the substitution parameter. The higher the elasticity of substitution, the more mobile the factors in the economy are, so firms will be more eager to substitute labor with capital and vice versa when the relative price of the factor decreases or increases. While for the working hours the logic with substitution may seem anecdotal, for the quality more intuition can be provided to link the theoretical model with the empirical setting.

Carroll & Young (2018) discuss how the elasticity of substitution affects the growth possibilities. Using a simple neoclassical model with only two factors of production, capital, and labor, the authors derive the relationship between elasticity of substitution, economic growth, and inequality. They show that countries which higher substitution parameters have larger economic growth and inequality. Finally, the authors relate their results with the real-world data by estimating their model and pointing out that countries with high elasticity of substitution (usually larger 1) are the developed or the advanced economies, while countries with small elasticity of substitution are the developing or the emerging ones. Furthermore, the relationship between labor and economic growth will be positive for the counties with a higher elasticity of substitution. However, the effect will not be linear over time but will exhibit a diminishing return to scale. Mallick (2012) uses cross-country analysis to support that claim. For his sample of 90 countries, he finds that the growth rate increases with the value of elasticity of substitution.

The article by Carroll & Young (2018) creates a straightforward link between elasticity of substitution and growth possibilities. However, as the model in the article does not distinguish between types of labor, the result is not perfectly applicable to my setting. The effect of the labor quality, or skills of workers, on the economy may depend both on the size of the economy and the elasticity of substitution between skilled labor and capital. The assumption is that in the more developed countries the ability to replace capital with skilled labor may be realistic under certain conditions. Zhang (2015) investigates the relationship between elasticity of substitution and economic growth in the case of two types of workers in the economy. The author shows that there is a higher correlation between economic growth and the high-skilled, low-skilled wage gap when the substitution parameter for the production function is higher. This result partially proves the idea that the higher value for the substitution parameter may be a sign of the overall development of the economy. Similar results are found by Mattauch et al. (2022) who study the wealth inequality in the OECD countries. Furthermore, the authors directly specify that the switch between developed and developing economies happens at the 0.82 thresholds for the elasticity of substitution.

Furthermore, it is possible to relate the economic growth, the elasticity of substitution between capital and labor, and the investment in the quality of labor, i.e. education expenditures (Gamlath & Lahiri, 2018). Furthermore, the relationships between education and economic growth are indirect and education affects the growth only through the labor channel. This effect is further reinforced by the elasticity of substitution. As in the more developed societies where the average education level is higher the marginal products of additional education are lower (Aydemir & Yazici, 2019). Gamlath & Lahiri (2018) prove this hypothesis using an overlapping generation model and shows that optimal tax is higher for the economies with a higher elasticity of substitution. The last result partially supports the one seen in my model for the economy with arbitrary high σ. Therefore, the level of education may be a reasonable proxy for the development of the ICT sector and its sensitivity to government support programs.

To sum up, the results of the model discussed in the previous section find support both in the theoretical and empirical literature. The effect goes through the labor channel directly, or the employment in the knowledge-intensive sectors. The ICT sector is one of these highly knowledge-intensive sectors, thus, the results found in the literature about the elasticity of substitution between labor and capital being higher for the countries which are more developed may be exploited as an identification strategy to solve the endogeneity issue. These differences between two economies with two levels of elasticity of substitution are even more present when the government intervenes. To further study the differences in the effects in the next section I will consider the different specifications for the analysis of intervention effects on economic growth taking into account the importance of the high-skilled labor channel.

5 The effects of support policies for ICT sector: panel data analysis

To support the results from the theoretical framework I conduct the empirical study of the European IT markets in the 21 century. To make the results more universal I use data on the support and tax break policies as a proxy for capital tax in my theoretical model. This assumption may not be perfect as European R&D-supporting programs consist of both fiscal and non-fiscal forms of support. However, the insights from the analysis of this proxy may still be useful for understanding how the economies regulate the ICT sectors and if these regulations are efficient in terms of the GDP growth. Furthermore, to explain better the effects of the elasticity of substitution parameter on the growth possibilities, I study separately the developed and developing economies and show that the effect is indeed different.

5.1 Data and Empirical strategy

5.1.1 Data

I use data from the Eurostat database on the number of employees in the innovative firms, R&D expenses of the innovative firms, and shares of university graduates in the IT-related spheres. The majority of the macroeconomic indicators including the CPI, population growth, educational indices and the indices for the access to internet are obtained from the World Bank Database. The data is annual from 1998 till 2020. The data on the graduates consist of students who received Bachelor and Masters degrees in Mathematics, Science or Computing, i.e. tertiary education levels 5-6, Eurostat (2021). The dummy variable which shows if the country was implementing innovation-supporting policies in year t is constructed using information about European countries' ICT support programs, specifically tax breaks for the innovations and R&D. The information was obtained from official European policy reports which are publicly available on the official government websites. To construct innovation supporting policies dunny I use both tax reduction and additional government investments for the ICT firms and their durations. The data on the programs, their durations, and goals was collected from the official OECD (2021) website which describes the ICT-related policies and national surveys. For the analysis of advanced/developed and developing counties I use definition from the World Bank ranking of countries and name the country as a developed one if the country was listed by World Bank as a developed in the beginning of 21st century (2000,2001,2002 and 2003 years). This conservative definition for the developed countries allows to study how the innovation supporting programs affect countries which had similar capabilities when the ICT sector was starting to grow. In order to avoid issues with non-stationarity, all the variables are converted into growth rates.

5.1.2 Empirical strategy and historical background

Since the beginning of the 90s, several European countries have introduced programs to support the ICT industry and R&D in the private sector. For example, in 2001 UK government announced a program that provided tax breaks for innovative firms Guceri et al. (n.d.). The duration of the program was 5 years and the next such program started only in 2011. Romania in 2001 adopted a similar policy which included personal income tax breaks for programmers Manelici & Pantea

(2021). In 2013 the program was expanded to all the IT sector workers. However, after almost two decades there is no converge between UK economy and the Romanian one while these both economies experiences shocks during this period of time. Thus, this anecdotal evidence suggests that the effects of these two programs were different proving the point that the efficiency of policy depends both on the initial characteristics of the economy and the some external factors. Furthermore, the policy supporting the ICT industry may not have any effect on the real economy unless a sufficient number of eligible firms are operating on the market. The effectiveness of the program also depends highly on the initial characteristics of the ICT industry. The results from Singapore support the importance of the local ICT market developmetn as well Wang (2018).

The endogeneity of the ICT sector density is straightforward in the case of Europe where the majority of IT centers are located in economically more developed and educated regions. One of the signs for the development of IT is the portion of university graduates who have degrees in Math, Computer Science, and related spheres. However, this indicator may also affect the economic growth via other channels including engineering, etc. However, according to the modern literature on growth the size of the effect through the ICT channel is prevalent and leads to the most significant changes in GDP growth, thus, allowing me to focus specifically on the ICT and innovations channels Desmarchelier et al. (2013). This assumption allows me to use a portion of graduates as the exogenous instrument for the employment in the ICT sector.

While the number of the employed in the innovative firms is an endogenous variable which may be affected both by its previous realizations and some external factors like the perception of the IT industry and the specialization of the country and region, the change of this indicator can be assumed to be ergodic and stationary. However, it is still highly dependent on the number of graduates from the IT-related universities, thus, I have to assume the following first stage:

$$D_{ij}\Delta ITf_{it} = \sum_{j=0}^{J} \beta_j G_{it-j} + \kappa X_{it} + \epsilon_{it}$$

where ΔITf_{it} is the change of the number of workers employed in the ICT industry according to the Eurostat data, X_{it} are country- and year-specific and other socio-economic controls, which are assumed to be exogenous, G_{it-j} is the number of the graduates in the period t-j. In all the regression throughout the work I use $j = 1$. The number of lags is chosen according to the information criteria. Furthermore, it is commonly assumed that it takes from 6-12 month for the graduates to find job on the ICT market (Millán et al., 2019). Thus, the choice of the lags is justified both by statistical reasoning and economic intuition.

The main equation for the second stage is catching the effects of the ICT-suppoting policy (D_{ij}) and the number of employees in the ICT sector (ITf_{it}) on the various economic indeces:

$$y_{ij} = \alpha_i + \alpha_t + \gamma D_{ij}\Delta ITf_{it} + \sigma X_{it} + v_{it}$$

Where y_{ij} are variables of interest which represent economic growth, inequality or unemployment rate, α_i and α_t are country and year fixed effects. The main variable of interest is the cross-product of dummy for innovation supporting policies and change in the number of innovative firms. X_{it} is a set of controls which include fixes effects, population, economic and social controls. All the variables in the equation above are transformed into growth rate to avoid issues with non-stationarity.

The mechanism behind the estimated equations may be summarised in a following more straightforward way. The increase in the number of university graduates with IT-related degrees leads to the increase in the ICT sector activities, both IT start-ups and the employment in the existing innovative firms. The quality of the labor force is, thus, the main driving force for the ICT sector growth which sequentially contributes to the overall development. This intuition follows closely the one results from the theoretical framework where the number of employees in the ICT sector was the main driver of the economic growth for the whole economy. This growth of the ICT sector will be additionally strengthened by the government policies which intend to increase both efficiencies of investment in innovation and employment in firms doing R&D. These policies should have the same effect as the decrease of the capital tax in the model from chapter 3. However, the effect of support may be negative if the inequality in IT firms' size is relatively high or the economy has relatively high elasticity of substitution between capital and labor. In the case of the Singaporean ICT sector, small local IT firms were pushed out of the market by multinational corporations which were attracted by the government support policies. The destruction of the local IT market led to a decrease in long-run growth as corporations were leaving the region after the finish of the program. Thus, the policy may not always have a positive effect on the growth as the government expects. Therefore, the policy supporting the ICT sector will slow the innovations and lead to the stagnation of firms doing R&D. The inequality in the ICT sector is more noticeable in the developed economies where the existing corporations historically tend to have larger shares of the market, whereas in the developing economies the IT firms market is more competitive.

5.2 Estimation and discussion

Firstly, I show that the use of the Difference-in-Difference approach with simple OLS regressions in this case is not appropriate both from the statistical and economical perspectives. To use the Difference-in-Difference approach I have to check the parallelity assumption, or the assumption that countries were identical before the treatment. The treatment group in my case consists of countries that started to use innovation incentivizing programs, while the control group consists of countries where IT firms have never received any form of government support. The countries were treated in different periods and the treatment in this case is continuous and not a dummy variable. This approach should provide better understanding of the effects and be more robust to the differences in countries. As Europe consists of counties with different economic and historical backgrounds, this assumption is likely to be rejected. The statistical visual examination of the data shows that the trends for both groups do not look similar before the treatment, thus, the parallelity assumption, in this case, is rejected. The blue and red line of the figure 3 are not identical. The actual statistical test based on the regressions with dummies for years also rejects the assumption about two groups being identical before the policy's implementation. Thus, simple OLS approach is not justifiable for this sample.

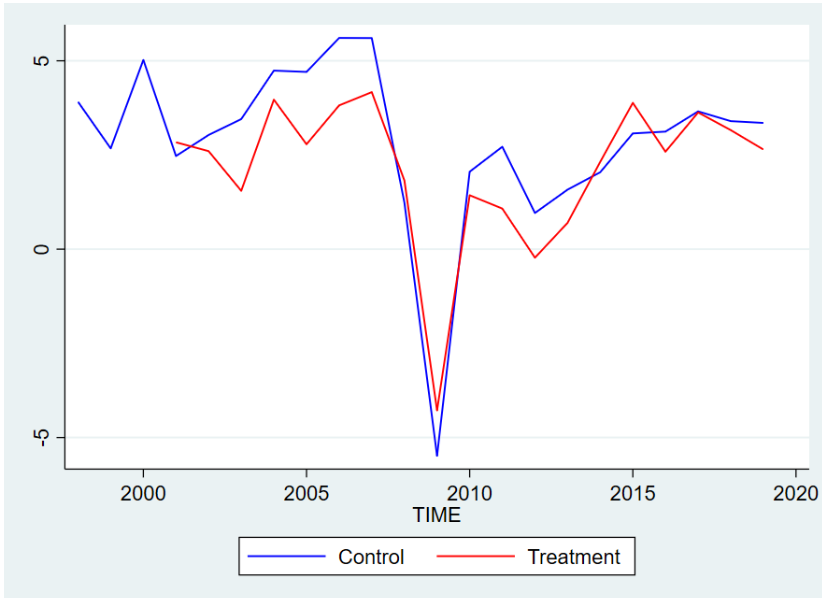

Figure 3: Visually check for the parallelity assumption

For the IV approach, I have to use several assumptions which were partially discussed above. Firstly, I assume that the effect of policy implementation and number of IT workers are endogenous variables and are affected by the shares of graduates with relevant for IT sectors degrees. Secondly, I assume that the number of graduates does not affect the GDP growth through any other channel except for the ICT sector. While this assumption may not be realistic it is highly supported by the modern literature on ICT development Desmarchelier et al. (2013). Results for the first stage are presented in the table below:

	ICT employment	
ICT-related education	25.80***	28.64***
	(9.36)	(9.58)
N	653	653
R^2	0.117	0.131
Time FE	No	Yes
Country FE	No	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Estimation of the first stage

The first stage for IT employment and IT-related education is strong and the sign of the effect is positive which follows the economic intuition. Another interesting insight that the first stage provides is the high importance of the country fixed effect which can hint that the country-specific effects play a crucial role in the efficiency of the ICT sector and related policies, or the historical level of the development plays a significant role in the sign of the effect.

	GDP	GDP	GDP	GDP	GINI	Unemployment
Policy ×	-0.0165	-0.0142	-0.0144	-0.00584	0.00170	-0.0181
×ICT employment	(-0.58)	(-0.65)	(-0.66)	(-0.39)	(0.17)	(-1.34)
N	565	565	565	523	410	523
R^2	0.240	0.349	0.347	0.577	0.892	0.609
County_FE	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes	Yes	Yes	Yes
Geo_controls	No	Yes	Yes	Yes	Yes	Yes
Financial_controls	No	No	Yes	Yes	Yes	Yes
ICT_controls	No	No	No	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: 2SLS estimation

The results of the IV regression show that the coefficients near the cross product of IT workers and innovation support policy are insignificant for different specifications. The absence of the effect is present also when the dependent variable is replaced by the GINI index and change of unemployment rate. The introduction of different controls including the population, inflation (consumer price index), and the intensity of the ICT sector does not affect the significance or sizes of effects.

The insignificance of the results may be partially explained by the differences in the European countries, i.e. the effect of policies in the more advanced ones may be more present than in the less advanced. To account for these differences I divide my sample into more developed and less developed economies according to the World Bank specification. The results for the estimation are presented below.

	Developed			Developing		
	GDP	GINI	Unempl.	GDP	GINI	Unempl.
Policy×	-18.08**	-10.40	10.13*	23.87*	-28.18	-0.953
×ICT Employment	(-2.26)	(-0.97)	(1.24)	(1.21)	(-0.72)	(-0.09)
N	257	212	257	251	192	257
R^2	0.646	0.857	0.770	0.567	0.863	0.466
County_FE	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes	Yes	Yes	Yes
Geographic_controls	Yes	Yes	Yes	Yes	Yes	Yes
Financial_controls	Yes	Yes	Yes	Yes	Yes	Yes
ICT_controls	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Comparison of developed and developing economies

Considering samples of more advanced and less advanced countries shows that insignificance in the pooled case may be caused by the effect of the underdeveloped economies and different signs for the two groups of countries. For the developed economies the effect of tax break policy significantly decreases the GDP growth. In high-income economies tax break policies can destroy the incentive for the big IT firms to invest in R&D, thus, making an investment in innovations less efficient. The loss of the efficiency of the ICT sector leads to stagnation for the rest of the economy. While the effect on the GINI index in both cases is negative and insignificant, the size for the developing economies is much larger. Furthermore, for the developed countries there is a positive and significant effect of the ICT support and size of ICT sector on the unemployment. However, this effect may be explained by the predatory behavior of big companies, this may also sign that the increase in the automation and robotization leads to the loss of jobs for the low-skilled workers. This explanation partially opposes the results by Acemoglu et al. (2014) about benefits from innovations for both high- and low-skilled workers. For the developing countries there is insignificant decrease in the unemployment rate. Additionally, the coefficients in the developing countries are larger which can indirectly indicate that the ICT sector in these economies can lead to more noticeable changes. Thus, programs for these countries may be both riskier in terms of the unemployment rate and inequality and more beneficial in terms of GDP growth. The general insignificance of the results may signal that the ICT sector is not yet the main driver of economic growth and development in Europe which supports the ideas by Bloom et al. (2012). The results of these regression partially support the model discussed in the chapter 3 as the effect for the countries are indeed different. This may also contribute to the literature on the elasticity of substitution and its role for the level of economic development.

5.3 Alternative identification strategy

To check the robustness of my previous results I use different instrumental variable and run the same regressions for the two samples of developed and developing countries. As an alternative instrument I use access to the internet, as this variable has similar effect on the employment in the ICT sector as the education and do not have any direct effect on the GDP growth itself. The intuition behind the relationship between employment in ICT sector and Internet access may be described in the following fashion. Modern ICT sector relies significantly on the cloud technologies and internet in particular, thus, the countries, which ensured the quality of connection faster, were the first hosts for the ICT firms. These relationship may have persistent long-run effect on the economic development. Furthermore, the literature supports the hypothesis that internet access is relevant for the ICT sector in general but is not a driver of the economic growth. While the last assumption about the exogeneity of the internet access may not be universally true, for the European countries with high concentration of the big cities this assumption may hold. The modern literature on the role of internet for the regional development also supports the hypothesis that for the Europe the introduction of internet were done almost uniformly for the different countries Orviska & Hudson (2009). Thus, this proxy satisfies the exclusion restriction and gives a strong first stage regression, which makes the instrument suitable for the robustness checks.

	ICT employment		
Internet access	92.682***	11.098	48.390*
	(2.35)	(1.42)	(1.65)
N	698	698	653
R^2	0.495	0.988	0.989
Time FE	No	Yes	Yes
Country FE	No	No	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Estimation of the first stage

From the first stage the can see that coefficients for share of population with the access to the internet have significant effect on the employment in ICT for all the specifications. These result supports the relevance of the instrument. The signs and sizes of coefficients also coincide with the ones in the initial regression with education which may signify that the instruments catch catch the same interrelationship in the economy.

Thus, the internet access has a positive effect on the share of people employed in ICT sectors. This result is straightforward because modern ICT sector depends on the cloud services and long-distance communication. In the countries with high degree of internet coverage it may easier to find jobs and create start-ups. Therefore, the first stage is strong both from the statistical point of view and from the economic perspective.

	Developed			Developing		
	GDP	GINI	Unempl.	GDP	GINI	Unempl.
Policy×	-31.74	-14.04	25.18	14.02	-7.957	-1.403
×Employment in ICT	(-1.28)	(-0.31)	(0.27)	(1.19)	(-0.10)	(-0.33)
N	214	183	224	230	168	230
R^2	0.495	0.827	0.737	0.618	0.927	0.394
County_FE	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes	Yes	Yes	Yes
Geographic_controls	Yes	Yes	Yes	Yes	Yes	Yes
Financial_controls	Yes	Yes	Yes	Yes	Yes	Yes
ICT_controls	Yes	Yes	Yes	Yes	Yes	Yes
Edu_controls	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Comparison of developed and developing economies under different identification strategy

From the table above, the coefficients for the second stage have similar signs with the results for the education from the main regression. However, the results in this case tent to be less significant which may be a sign that this instrument is worse in explaining of the effect of ICT sector on the economic growth. Furthermore, there are some minor differences in sizes as table 6 shows that effects for the developed countries are larger for all the specifications. The results stay the same with the introduction of additional controls. From this robustness check, I can still conclude that there is no significant effect of the of the ICT-supporting programs on the GINI index for both samples and all the specifications.

6 Discussion

In this chapter, I will discuss some explanations for the results obtained in the previous sections paying specific attention to the real-world implementations and economic intuition behind my conclusion. At the end of the section, I will discuss the possible limitations of the study and future extensions.

6.1 Channels

Firstly, I will discuss possible channels through how the ICT-supporting programs, employment in IT firms, shares of people with IT-related education, and internet access may affect the economic growth possibilities for the different economies.

6.1.1 Human capital channel

Education is one of many factors in the long-run growth of the economy Mauro & Carmeci (2003). Education may both increase the quality of human capital and ensure the efficient usage of other production factors, thus, leading to an increase in production. This effect may be strengthened for the ICT sector where education and skilled labor play a crucial role. While the importance of the education for the ICT sector may be less visible for the developed countries where there is no severe heterogeneity in the education levels among the population and regions, for the developing countries and emerging markets the effects of education on the economic growth possibilities are more present Apergis et al. (2022). The results above also signify that for the governments in the less developed region introduction of the support programs, which will encourage employment in the knowledge-intensive sectors, may be an optimal strategy to achieve long-run growth faster.

Thus, the effects of education on economic growth go through the employment channels. While these results may also signify that the ICT sector itself is only a proxy for the real effect of education on growth, one may see that the effect is not universal for different countries with similar educational backgrounds (EU countries). Thus, the differences in the effects for the developed and underdeveloped parts of Europe prove that the level of development of local innovation markets is important. This result supports my claim that the programs which target the ICT sector and indirectly high-skilled labor may be harmful in some cases. While the introduction of such policies may create an incentive for the student of ICT-related programs to participate in the IT sector, these incentives may not be suitable for the economic environment and destabilize the markets by lowering the quality of products and destroying the economic barriers which were initially beneficial for both for firms and customers.

6.1.2 Competitiveness of innovations

One of the reasons why for the developed countries the ICT supporting programs may be less efficient and be harmful to the economic growth is the initial structure of the ICT market. For the countries where the ICT sector was created earlier, for the big companies there was enough time to gain market power and become competitive monopolists. Therefore, for the new firms, it may be more difficult to find their niche and achieve zero profit conditions. However, high entry barriers may have also the opposite effect creating incentives only for the most efficient companies to enter the market. The government intervention then will make such barriers even higher and will destroy the incentives for the newcomers in the developed countries. Thus, the programs will not lead to an increase in competitiveness and growth but to the growth in inequality and long-run stagnation.

For the less developed counties where the ICT sector may not be yet established, for the firms there are additional incentives to invest in the risky innovative products. In this case, government support can decrease the riskiness of the investment and further incentivize the participation of firms. However, such a process may still result in the growth of inequality, it should not be as steep as it may be for the developed countries. Furthermore, the duration of the support should play a crucial role for the developing countries as for small firms it may take more time to adjust and start operating on the market. The literature and analysis of the programs show that the majority of European countries usually create 5-year programs to support the creation of new ICT firms. However, the choice of duration may be affected by many factors my primer explanation is that the university education for a Bachelor's degree takes 4 years, thus, these programs target students and graduates who create their start-ups.

6.1.3 Redundancy of the less knowledge-intensive industries

The effect of the elasticity of substitution, which I use as a proxy for the level of economic development throughout the paper, may also enhance the growth possibilities and effects of policies on the ICT sector directly via the marginal product channel. The effect of marginal products and the relative prices of factors in the economy may be the source of the short-run economic growth. The ability of firms to substitute the capital with labor at a lower price may result in disadvantages for the non-knowledge-intensive sector where capital may not be easily replaced with high-skilled labor. Thus, for the firms on the ICT, the factor prices are relatively lower and their profits are higher. This hypothesis is supported in the theoretical and empirical literature for both developed and developing economies (Mallick, 2012; Kim et al., 2021; Grüner, 2009; Gamlath & Lahiri, 2018). Therefore, the introduction of the support policies for the ICT sector creates additional incentives for the investors to participate in the ICT sector ignoring other less profitable sectors. Thus, the effects observed in the empirical part of the study may be a consequence of the change in the elasticity of substitution for the ICT sector and not the growth of the ICT sector. This hypothesis may also explain the insignificance of the alternative identification strategy. The internet access may be higher for the developed countries with relatively higher elasticity of substitution, thus, the effect of policy will be indistinguishable from the effect of the development level proxied via elasticity of substitution.

6.2 Future extensions and limitations

The main focus of my study is the effects of the ICT sector on the economic growth and development of countries. While I pay specific attention to the effects of the taxes and tax breaks, this approach may be not universal as governments may use various ways to support the ICT sector using less denotative methods. Furthermore, the model provided in section 3 may not be universal for both developed and developing counties as there could be differences not only in the values of the exogenous parameters but also in market structure assumption. The sizes and signs of effects may change directly for the more complicated setting with more elaborate agents in the economy. The introduction of additional market assumptions and sector-specific functions may help to achieve a better fit of the data and more realistic results.

The focus on the European countries may also create biased results due to the unique characteristics of the European region. Close distances and mutual development of the countries may account for the inefficient results. Furthermore, the nature of the ICT sector does not allow one to study long series of data which may affect the results of the estimation. While the main focus of this analysis was on the effects on the different countries, it may be useful to study countries separately to identify the unique condition for the efficiency of the ICT support programs.

7 Conclusions

The growth of the ICT industry in the last decades has led to significant improvements in working conditions, production technologies, and knowledge exchange between countries. Both developed and developing countries strive to incentivize more IT firms to set up facilities and improve regional development via various channels including the creation of new job placements for recent university graduates. Governments may use various strategies to make the region more attractive for the new IT start-up. One of the ways is the provision of financial support and tax breaks for the firms that invest in R&D. However, as literature on ICT suggests the effects of such policies may be ambiguous, and depend on a number of parameters that are not necessarily well-defined to date.

In this paper, I study a general equilibrium model in which the CES production function is used for the description of the R&D firms and show that the theoretical results hold for the European countries. In this case, both intermediate and innovative goods producers use capital and labor which creates additional nontrivial market clearing conditions. In conclusion, I prove the hypothesis that increases in the capital income tax rate will have both positive and negative effects on the innovative sector depending on the elasticity of substitution between capital and labor on the innovative market. The sign of the effect can explain both the tax-shifting effect and the consumption effect. The relationships between these two effects are not determined uniquely and can differ for different values of the substitution parameter. In the simplest specification, for the higher values of the substitution parameter, a lower tax rate will be needed to achieve the highest growth rate. This result supports the idea that the CES production function helps to generate more realistic results than both its linear and Cobb-Douglas analogs. I use data on the European countries from 1998 to 2020 to empirically show that the results from the theoretical model hold. I implement the IV approach and focus on the labor market channel to identify the effects. The results show that for the developed counties the ICT-related policies are often harmful, while for the developing ones the effect is insignificantly positive. To sum up, the main aim of this paper is to show that taxation of capital may harm economic growth via the innovation channel which is considered to be one of the most important in the modern economy. Thus, governments must be extremely cautious when dealing with the regulations that may affect R&D, because this sector can be highly sensitive to the changes in the factor prices.

This paper supports the idea that the effects of ICT-related policies may not be beneficial for the economic growth and development of the region. The empirical study of European countries shows that there is no significant impact of such policies on growth, the GINI index, or unemployment. The absence of effects may be partially explained by the presence of the developing countries as the ICT sector may not be the main source of development. For the more advanced countries, there is a significant decrease in GDP growth with the increase in ICT sector support. The negative effect of support may signal that for the high-income regions, the policies in favor of ICT can discourage large corporations from investing more in R&D, which leads to the loss of the efficiency of the innovative sector. These results show that governments must be extremely cautious when dealing with the ICT sector. This thesis contributes to the growing literature on the role of ICT sector and ICT-related programs in the regional growth and development by combining theoretical and empirical approaches.

Summary

Researchers and policymakers pay attention to the ICT sector as innovation can improve economic growth. Firms invest in innovations to gain comparative advantages and increase profits, while society and consumers benefit from the higher quality of goods and services. The growth of the ICT sector may also allow the government to collect more taxes. Thus, for the government, it may be optimal to create an environment suitable for the ”Google” offices. However, in some cases, the government support programs may not be beneficial for the long-run economic growth and destroy incentives for ICT and non-ICT firms leading to the recession. In this thesis, I show that the efficiency of ICT support programs depends on the development of the economy, and for the more developed economies interventions may lead to a decrease in economic growth.

I use the general equilibrium model by Chen et al. (2017) with producers of innovations and Ramsey capital tax. I adapt the model and use the constant elasticity of substitution (CES) function with capital and labor inputs for the producers of innovations to study the effect of tax on economic growth under different levels of elasticity. Using the elasticity of substitution as a proxy for economic growth, I show that a tax decrease policy may be efficient for developing economies with low elasticity. I use data on European countries and their ICT support programs from 1998 until 2020 to support my theoretical result. I employ the IV approach to study the effect of support programs and the size of the ICT sector proxied via ICT employment on economic growth and use ICT-related education as an instrument for my main regressors. I show that for developed countries support has a significant negative effect on economic growth while for developing ones effect is insignificantly positive. These results support intuition from the theoretical models and contribute to the literature on the roles of the ICT sector and ICT related policies in the economic growth.

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Annexes: graphs and tables

Variable	Obs	Mean	Std. Dev.
GDP	733	2.664	3.382
Education	682	19.876	5.829
Policy	733	.393	.489
CPI	733	3.3	6.539
Patent	681	3629.956	9012.162
GINI	521	31.793	4.121
Unemployment rate	733	8.989	5.811
Internet access	733	57.653	27.705
Tertiary education rate	660	659640.3	954779

Table 7: Summary statistics for the main variables

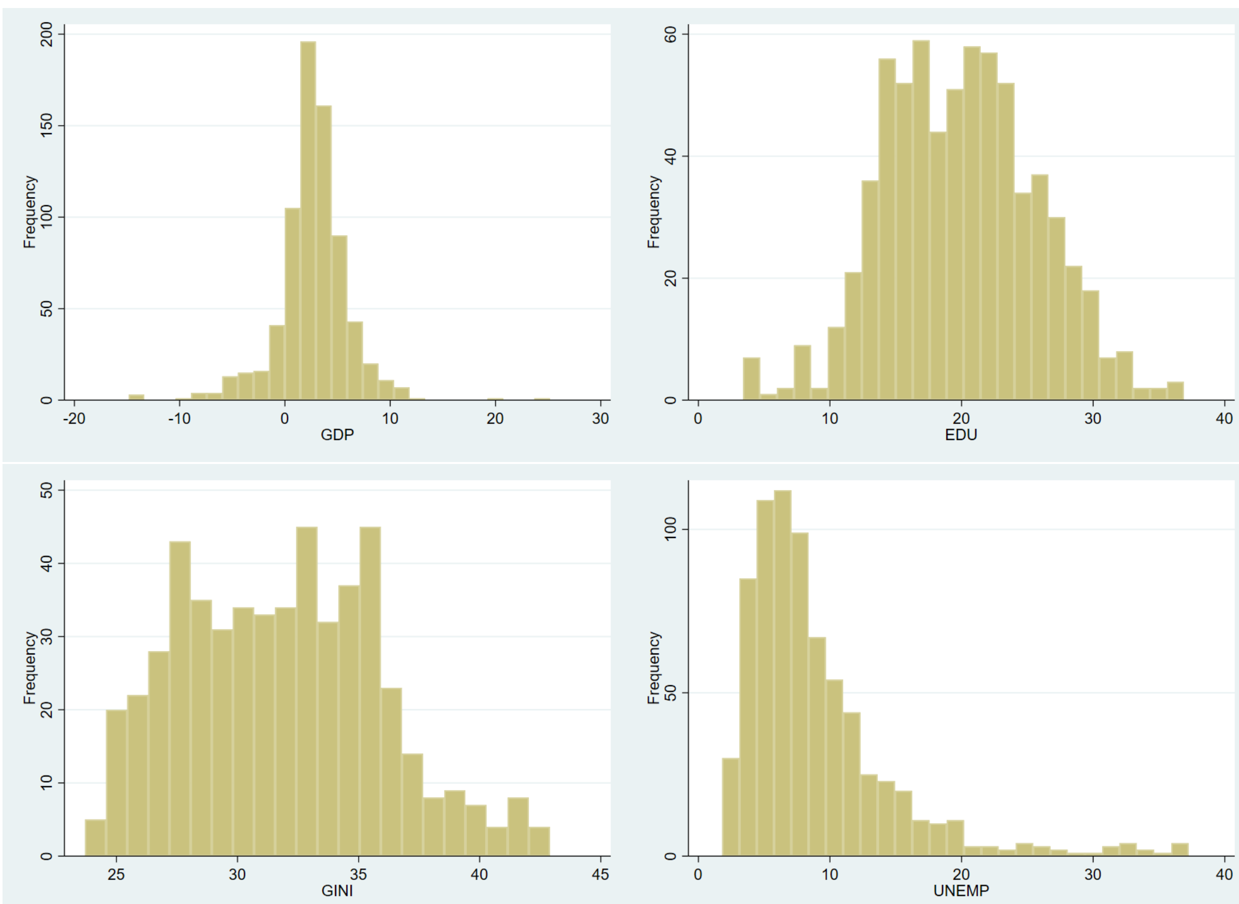

Figure 4: Distributions of the main dependent variables (GDP, GINI index and unemployment rate) and main independent variable (ICT related education)

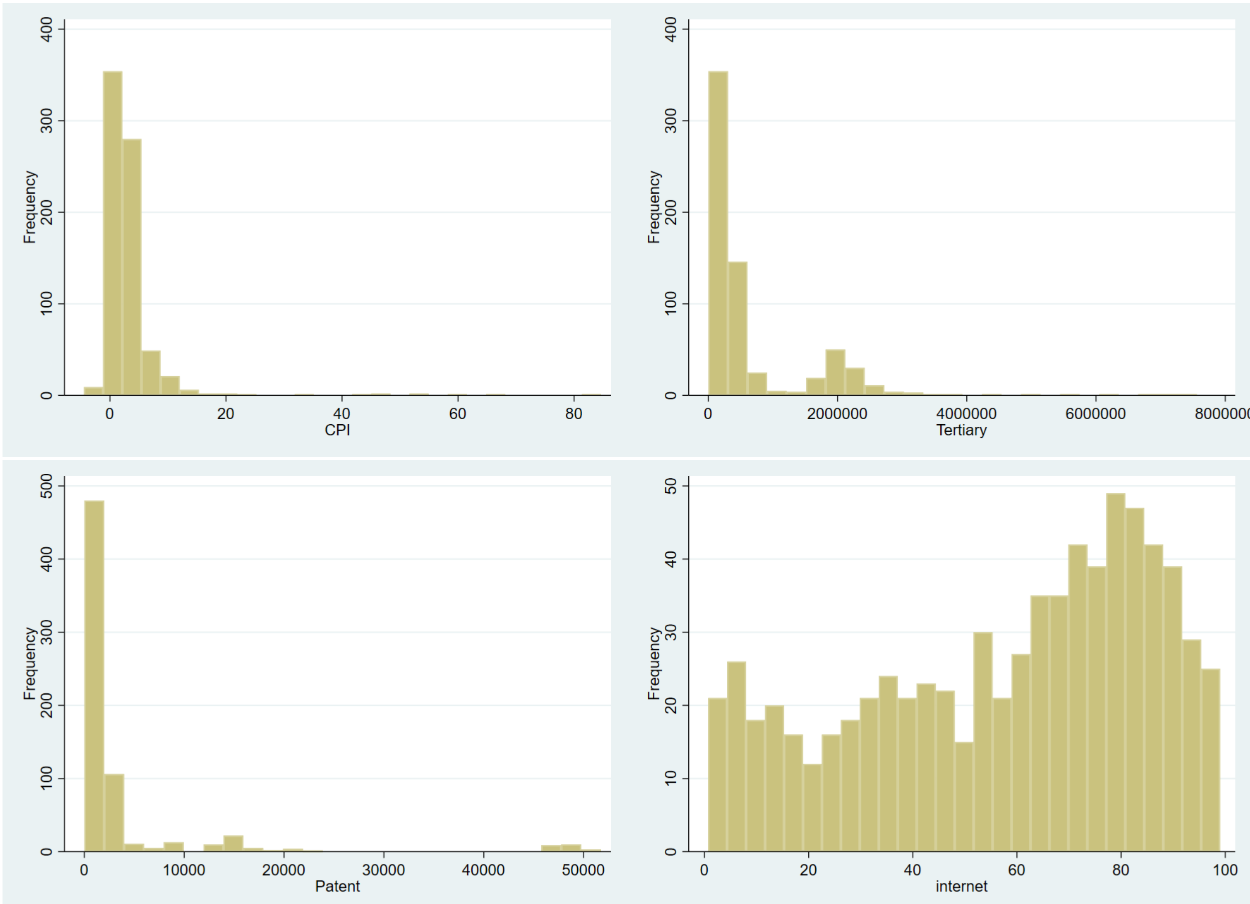

Figure 5: Distributions of the main control variables (CPI, Tertiary education and unemployment rate) and variable for the alternative identification (internet access)

Variables	GDP	Edu	Policy	CPI	Patent	Population	GINI	Unempl	Internet	Tertiary
GDP	1.000									
EDU	-0.028	1.000								
Policy	-0.127	-0.032	1.000							
CPI	0.017	0.107	-0.141	1.000						
Patent	-0.102	0.266	-0.015	-0.084	1.000					
Population	-0.089	0.284	0.114	0.155	0.738	1.000				
GINI	0.037	-0.053	-0.083	0.272	0.024	0.349	1.000			
UNEMP	-0.094	0.051	-0.114	-0.038	-0.093	0.003	0.414	1.000		
internet	-0.192	-0.213	0.477	-0.346	0.084	-0.058	-0.428	-0.241	1.000	
Tertiary	-0.028	0.156	0.174	0.107	0.598	0.923	0.428	0.029	-0.014	1.000

Table 8: Cross-correlation table

	Developed			Developing		
	GDP	GINI	Unempl.	GDP	GINI	Unempl.
polEmpGr	0.0226	-22.81	2.970	-79.04	-32.26	-0.804
	(0.00)	(-0.83)	(0.21)	(-1.12)	(-1.03)	(-0.22)
N	238	199	238	234	184	239
R^2	0.756	0.776	0.790	-0.061	0.851	0.496
County_FE	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes	Yes	Yes	Yes
Geo_controls	Yes	Yes	Yes	Yes	Yes	Yes
Financial_controls	Yes	Yes	Yes	Yes	Yes	Yes
ICT_controls	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Table for the main specification with two lags in the first stage

	Developed			Developing		
	GDP	GINI	Unempl.	GDP	GINI	Unempl.
polEmpGr	12.73	-0.502	-14.17*	34.29	-31.49	2.244
	(1.16)	(-0.07)	(-1.81)	(0.83)	(-1.17)	(0.83)
N	201	170	201	208	165	208
R^2	0.722	0.872	0.816	0.603	0.875	0.268
County_FE	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes	Yes	Yes	Yes
Geo_controls	Yes	Yes	Yes	Yes	Yes	Yes
Financial_controls	Yes	Yes	Yes	Yes	Yes	Yes
ICT_controls	Yes	Yes	Yes	Yes	Yes	Yes
Edu_controls	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Table for the alternative specification with two lags in the first stage