Charles University in Prague
Faculty of Social Sciences
Institute of Economic Studies

MASTER'S THESIS

Principles of Information Economy and Impact of IT on Company's Value Added: A Cross-Industry Analysis

Author: **Bc. Adam Láníček**
Supervisor: **doc. Ing. Tomáš Cahlík, CSc.**

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature. He further declares that this thesis was not used to obtain any academic degree in the past.

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Prague, January 5, 2015

Signature

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Abstract

The industrial age was bound to end when the microprocessor was invented. Even though the classical economic theory applies for today as well as for the 1960s, the last thirty years were symptomatic by the change of the fundamental characteristics of the economy and information technology plays a key role in this process. The aim of this thesis was to describe the principles and micro- and macroeconomic phenomena present in the New Economy of today, the challenges that the companies face in this environment and, finally, to conduct a cross-industry analysis on the impact of IT on company's performance, namely value-added. The empirical results did not show any clear patterns among the industries and therefore no significant relationship between the share of information technology assets of total assets and company's value-added could be proven. One of the reasons for that could be the technical issues regarding the statistical measurement of IT which also remains the biggest challenge for the researchers in this field.

JEL Classification	O330
Keywords	New Economy, Economics of Information Technology, IT impact, IT impact on industries

Author's e-mail	a.lanicek@lanicektransport.cz
Supervisor's e-mail	cahlik@fsv.cuni.cz

Abstrakt

Po vynálezu mikroprocesoru byla tehdejší průmyslová ekonomika odsouzena k záhubě. I přesto, že klasická ekonomická teorie je stále aplikovatelná stejně jako v 60. letech minulého století, posledních 30 let se vyznačovalo změnami v podstatných charakteristikách ekonomiky, přičemž informační technologie v tomto procesu hrají klíčovou roli. Cílem této práce bylo popsat principy, dle kterých Nová ekonomika funguje, mikro- a makroekonomické jevy, kterými se vyznačuje a výzvy, kterým v tomto prostředí současné podniky čelí. Práce byla zakončena empirickou meziodvětvovou analýzou na téma vlivu IT na výkonnost podniku, konkrétně na jeho přidanou hodnotu. Studie neobjevila žádné jasné zákonitosti a statisticky významné vztahy mezi podílem IT aktiv na celkových aktivech. Jedna z možných příčin mohou být problémy technického charakteru, kterým statistika čelí při odhadování množství IT aktiv, což zůstává i velkou výzvou pro ekonomický výzkum i do budoucna.

JEL klasifikace	O330
Klíčová slova	New Economy, Nová ekonomika, Ekonomie informačních technologií, Dopad IT na odvětví ekonomiky

E-mail autora	a.lanicek@lanicektransport.cz
E-mail vedoucího práce	cahlik@fsv.cuni.cz

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Acronyms

IT	Information Technology
OLS	Ordinary Least Squares
GDP	Gross Domestic Product
NAICS	North American Industry Classification Systém
SIC	Standard Industrial Classification

Master Thesis Proposal

Institute of Economic Studies
Faculty of Social Sciences
Charles University in Prague

Author:	**Bc. Adam Láníček**	Supervisor:	Doc. Ing. Tomáš Cahlík CSc.
E-mail:	a.lanicek@lanicektransport.cz	E-mail:	cahlik@fsv.cuni.cz
Phone:	+420607650517	Phone:	222112318
Specialization:	*Finance, finanční trhy a bankovnictví*	Defense Planned:	June 2013

Proposed Topic:

Theoretical Approaches to Modern Information Economy

Topic Characteristics:

During the last decades, the structure of the world economy has changed. Even though the market forces are still working in the same direction, nowadays we can observe some economic phenomena that were unobservable in the pure industrial economy. The thesis Theoretical Approaches to Modern Information Economy will be therefore mainly devoted to the application of classical theoretical micro- and macroeconomic concepts and relationships, especially of those whose presence is typically assumed in the modern information economy of the 21st century. Among other topics, the thesis will discuss various trends, such as low marginal costs, economies of scale both on the supply and demand side, price discrimination, tendencies to standardize, network effects, lock-in concept and the frequent complementarity of the products. Author's aim is to provide a synthesis of the approaches based on the recent literature, apply the theoretical approaches to discuss the real cases and to infer some of the implications for business strategy and public regulation.

Hypotheses:

1. Increasing significance of information technology in some industries pushes the marginal costs of production to very low or zero levels.
2. Consumer switching costs of the goods produced or services provided by the IT or IT-related industry are significantly higher than it is usual on the other markets.
3. The degree of the world's interconnectedness is positively correlated with the amount of the price discrimination present in the economy.

Methodology:

The thesis will start with a review of the literature relevant to the information economy, its foundations as well as with the definitions of the basic micro- and macroeconomic concepts of phenomena present in the modern economy. Further on, different approaches of the various authors towards these will be synthetized. On the following pages, the real world cases found in the literature will be analyzed using this framework, showing the existence of the previously named phenomena in practice. Based on this analysis, the author will state the implications for the corporate strategy and public regulation. To conclude the thesis, the author will try to infer recommendations relevant for corporate strategy and public regulation.

Outline:

1. Development towards the modern information economy
2. Microeconomic and macroeconomic phenomena in the information economy
   a. Low marginal costs in production
   b. Economies of scale
   c. Price discrimination
   d. Tendencies for standardization
   e. Network effects and lock-in concept
3. Real-world cases discussions
4. Corporate strategy and public regulation implications

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Author

Supervisor

1 Introduction

In the 20th century, the world economy experienced unprecedented growth. Although being interrupted by the World War I, Great Depression and World War II in its first half, the industrial revolution in the 19th century laid down the foundations for the industrial economy that served the society as an instrument for the greatest creation of wealth in human history. One can interpret the word “revolution” in many ways, all of which would probably involve substantial and rather quick changes in the society. From the economic point of view this is not quite true, though. The growth patterns do not usually exhibit sudden soars as a result of a cutting-edge invention. When steam machines, electricity and automation techniques were introduced, it did not lead to significant increases of the world’s GDP at once, as one might expect. Rather, it slowly enabled new sectors in the economy to flourish, sectors that were more productive in comparison with the older ones. After labour and capital were reallocated to take advantage of the new technology, bursts of combinatorial creativity and innovation occurred in years that followed, influencing and enhancing stable economic growth for the decades to come. It is, therefore, not the fundamental invention that fuels the economic growth – it is rather the economic climate it generates with entrepreneurs’ and investors’ desires to take advantage of it.

Every such change on a macroeconomic level comes inherently hand in hand with a change in the structure of markets where microeconomic behavior of the agents is determined. As it is company’s raison d’être to make profit and its profit function is dependent on the market structure and bearing in mind that the structure is changing continuously, a business can never rely on market positions already achieved in past and has to adapt its processes to a turbulent economic environment promptly. The fundamental laws of economics are working the same way, the only thing that changes is technology and businesses have to adjust their strategy in order to remain competitive and maintain their market share. By their definition, the features of information economy were expected to bring efficiency gains to the markets. The knowledge of market agents can be easily and quickly transmitted to different corners of the world, leaving less space for goods prices to deviate from their equilibrium levels. When it comes to information technology economics, the topics of the interest are non-standard cost structures, easily performed price discrimination, patents, network effects and lock-in concept.

The first objective of this thesis is an analysis of these phenomena. This includes the analysis of the principles shaping the modern economy with a thorough definition of the micro- and macroeconomic theoretical concepts especially relevant to it. First crucial aspect are low or zero marginal costs, intuitively implying that producing additional unit of goods is negligible even when the produced amount is very high. Price discrimination allowing the producers to extract a significant fraction of the consumer's benefit from the trade that takes its place in the economy in various forms will be defined as well. So will be the network effects and lock-in concept, both of which are also a significant feature of the New Economy.

The second part of the thesis lays theoretical groundwork for the empirical part of the thesis provided in the last chapter. The concept of production function will be discussed, along with the literature survey on the impact of information technologies on cost structures and labour force in a firm. The aim of the last part of the thesis is to estimate the impact of IT capital utilization on value-added on the sample of 19 US industries for the years 1998-2002. For the familiarity with the current economic environment, the first chapter of the thesis will be devoted to processes and developments that lead towards the new economy, as it is often described in the literature. Further on, based on the survey of relevant literature sources, the basic micro- and macroeconomic concepts relevant to information technology, some of which were already mentioned above, will be defined. The last chapter will be devoted to an empirical cross-industry analysis of the influence of IT on business performance, namely value-added.

2 Information Economy

2.1 A techno-economic paradigm

During the last two or three decades, the world of commerce has experienced a fundamental change. All market agents ranging from producers to customers create an economic environment that is hardly comparable to the 1960s and even 1970s. Customer consumption patterns differ as a result of introduction of information technology. Earlier they were used to shop in brick-and-mortar shops, now they visit websites to make a purchase. The very same websites and providers of e-commerce are tracking their moves in order to be more efficient when providing goods for them in the future.

Information technology is at the root of all the socioeconomic changes that the mankind has been through in recent years. The ability to store, analyze and communicate data mined from every possible area of human activity changed everything ranging from business world to education. The executives have to apply elasticity, marginal productivity and market structure principles while bearing in mind the peculiarities of the new information economy. Information technology is a significant determinant of the market structure and shapes markets while still going through the process of constant improvement and change. It is reasonable to assume, therefore, that the markets will follow its development.

When trying to understand the processes underlying the recent changes, an evolutionary model developed by Joseph Schumpeter called Mark II comes in useful. He suggested that the process of technological change in the society consists of three phases as described by Andersen (2012):

1. **Invention**

   This phase involves a generation of random new ideas and can be envisioned as a scientific brainstorming. If one of the ideas is regarded as a potential breakthrough, the process continues to the innovation phase.

2. Innovation

Venture capitalists and government set in and a deliberate research with a clear goal takes place. As this is very risky to undertake, only government and venture funds are willing to participate.

3. Diffusion

The third stage is characterized by the actual occurrence of the new technology. The impact is measured by the reactions of the economy. In order to reach the diffusion phase, significant amount of resources has to be allocated into the development of new products and technology.

It is crucial to distinguish between innovations in the Schumpeter's world and minor changes that are present in the economy on a day-to-day basis. Similarly, technological change and the consequent sustained growth cannot be fueled by single innovations. While Schumpeter's thoughts capture the essence of the underlying processes in the early phase, a techno-economic paradigm is putting the issue into the institutional context. It suggests that when new products enter the market, it is the entrepreneurial spirit that enables the product to make its way through into the economy. For this process to be feasible, the institutional stability as far as the politics, international relations and national environment are concerned, needs to be favourable. On top of that, three conditions have to be met:

1. Continuous price decline of the commodity
2. Ability to penetrate other sectors thanks to the product's uniqueness
3. Unlimited source of the commodity

The persistent decline in price fosters the necessary increase in the size of the market which leads to broader utilization of the commodity, larger production and even lower price as a consequence, further deepening the process. Once adopted by a sufficient amount of agents, its technology slowly proliferates into most of the production processes and renders the former technologies used in production obsolete. In this phase it is important to design the production in a way that is enabling further innovations. As the newly adopted technology is spreading throughout the economy, the society has no choice but to accept it. [Perez (2009)]

Information technology meets the three above-mentioned criteria and the process of its adoption is very similar. The price of a computer chip is constantly falling, fulfilling the first condition. Its features attracted every possible sector and its stock is growing larger and larger. Therefore, it may be assumed that a new paradigm is in place.

2.2 New economy

During the second half of the 1990s the US economy was in the period of sustained economic growth, low employment and low inflation [Diwan and Kudyba (2003)]. This phenomenon was described by many authorities as the new era of limitless prosperity. Many have declared the existence of the New Economy, which was compared to the Second Industrial Revolution of the years 1860-1900. This industrial turning point provided the world with electricity and radio made the golden age of productivity growth possible. [Gordon (2000)] "New Economy" is a term used in research for analytical purposes as well. Its definition is not consistent among the authors, though. Gordon (2000) for example defines the New Economy as the synonym for the acceleration in rate of technical advance in information technology. His interpretation implies that the contributions made by IT prior to 1995 at the previous slower rate of technical advance should not be taken into account. Other authors may track the New Economy even to 1980s based on the particular topic they want to cover. Regardless of the time frame, New Economy was also called "new" because it denied the laws of economics that were believed to endure under every circumstance. From the point of view of a mainstream economist and his models, Diwan and Kudyba (2003) finds following inconsistencies:

- Sticky wages do not coexist with low employment.
- Low unemployment and low inflation do not go together.
- Sustained growth does not increase income inequalities.
- Corporate stock valuations do not adhere to traditional norms.

2.3 Information as the source of growth

In the last decade of 20th century, the world experienced an unprecedented economic growth based on information. In this sense, information is recognized as everything that can be translated into the digital form. Fuchs (2011) suggested in his work that information is costly to produce but cheap to reproduce – books that cost hundreds of thousands of dollars to produce can be printed and bound for a dollar or two, and 100-million dollar movies can be copied on videotape for a few cents. The use of information in this broad sense changed the economy enormously, the use of growing capacities in combination with financial innovation created an illusion of prosperity that had no limits, which is a phenomenon that occurs quite often when a cutting-edge innovation is introduced.

One important feature of modern information technology is, according to Pohjola (2001), the possibility it offers to unbundle information from its physical carrier which means that economics of information can be separated from the economics of things. The whole economy is changing its structure and even the portion of gross domestic product produced by the information technology industry is still rising at a rapid pace. For example between the years 1985-1995, as Pohjola (2001) reports, the information technology market grew at an annual rate of 14% which was about twice the growth rate of gross domestic product worldwide.

2.4 Stock indexes development 1990-2003

After significant investment into the information and communication technology sector and its development during 1990 the effort started to pay off. There were especially three events that stimulated investment in information technology according to Farrell et al. (2004):

a) telecommunications deregulation in 1996,
b) the “year Y2K” problem in 1998-99 and
c) “dot com” boom in 1999-2000.

Since a majority of companies from IT industry listed their shares on NASDAQ where they represented a substantial share of the index, development of the NASDAQ Composite index could serve as a good proxy for the development of the IT market.

During the years 1990-2000 the NASDAQ Composite index soared to its peak of 5000 points in the year 2000 to decline rapidly to 2000 points at the end of the year 2001. The main driving force was the dot-com boom that ended as quickly as it started.

With the year 1990 as the baseline for further development, the NASDAQ Composite increased more than twelvefold, whereas the S&P 500 only a bit less than fourfold. In addition to that, this figure does not capture the influence of information technology companies on stock market performance to its full extent – Farrell et al. (2004) identify the main reason as the rising share of the technology component in S&P 500 index from 6,5 percent in the year 1990 to 34 percent in the year 2000.

3 Micro- and macroeconomic phenomena present in ICT economy

This chapter will be devoted to definitions of micro- and macroeconomic concepts present in the modern information economy. As this part of the thesis aims to inquire the relationship between technology and market structure, this chapter will be devoted to developing a basic framework for the analysis. Market forces both in the information and industrial economy are working the same way, but as Farrell et al. (2004) suggests, second-order effects for industrial goods are often first-order effects for information goods. These encompass the issues discussed on the following pages. To simplify the analysis, the effects will be demonstrated in the perfect competition framework.

3.1 Low marginal costs in production

3.1.1 Classical economic theory of cost structures

In order to set its optimal production level and to maximize profit, every rational economic agent has to take into account the costs he incurs while conducting an economic activity. A common textbook example divides total costs into two groups:

- fixed costs (FC) - these are independent of the amount produced and represent a fixed amount to be paid for the production factors during a period *t*, typically in the form of a rent to capital (see equation 3.1).
- variable costs (VC) – are an increasing function of the amount produced within a period *t*. Their total amount therefore varies with the amount produced. Variable costs can typically be represented by wages to employees (see equation 3.2).

$$FC\ (t) = rK(t) \tag{3.1}$$

$$VC\ (t) = wL(t) \tag{3.2}$$

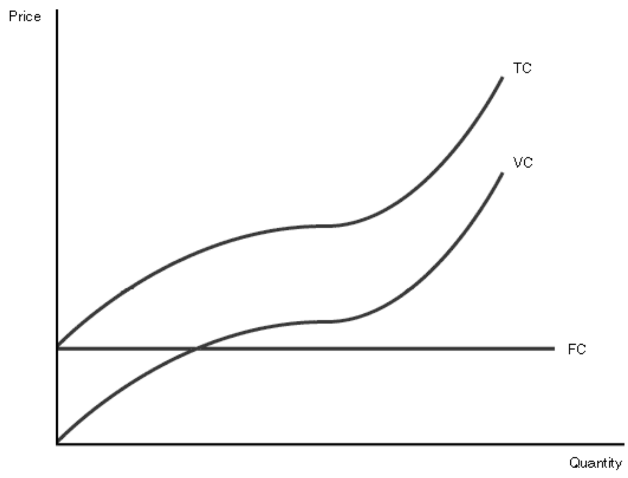
Then, fixed and variable costs represent total costs for the economic agent:

$$TC\ (t) = FC(t) + VC(t) \tag{3.3}$$

$$TC(t) = rK(t) + wL(t) \tag{3.4}$$

This relationship is depicted on the figure 3.1 below.

Figure 3.1 Total, variable and fixed costs



Source: author's drawings

Looking at the costs from another point of view, for purposes of our analysis it is especially crucial we distinguish between average and marginal costs:

- average costs (AC) – average costs are defined as costs referring to one unit of production. We can distinguish between average fixed costs (AFC) and average variable costs (AVC). The equations 3.5 indicate the relationships.

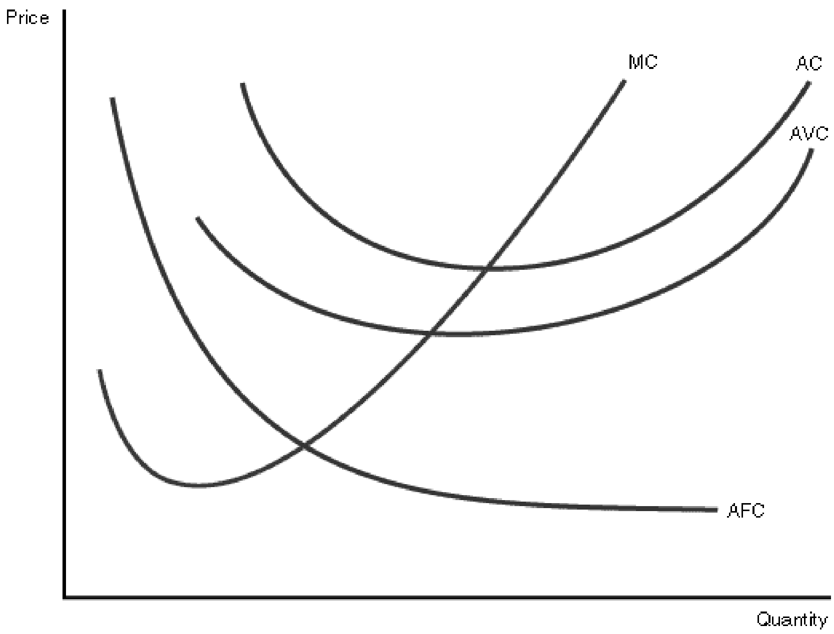
$$AC = TC/Q, \quad AVC = VC/Q, \quad AFC = FC/Q \tag{3.5}$$

- marginal costs (MC) – costs related to the production of one additional unit of product.

$$MC(t) = \frac{\Delta TC}{\Delta Q} \tag{3.6}$$

Figure 3.2 below depicts both average costs and marginal costs.

Figure 3.2: Average and marginal costs



Source: author’s drawings

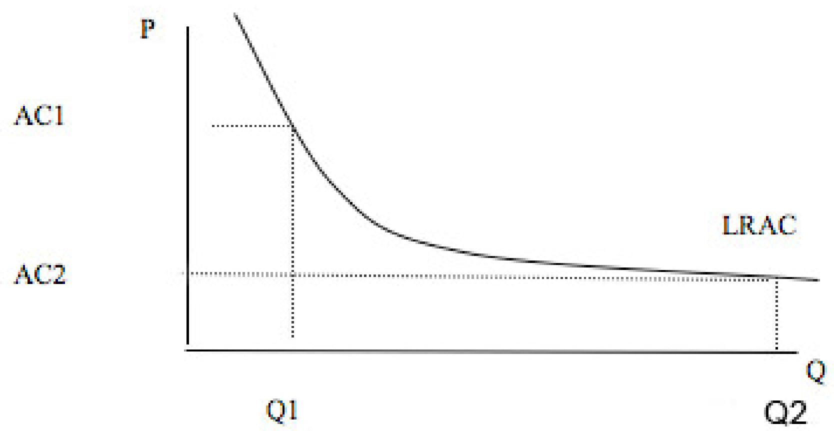
As the figure shows, average fixed costs are a decreasing function of quantity. This is quite intuitive – given the constant fixed costs, their average proportion that relates to one unit of product is decreasing with rising quantity.

At low quantities the marginal costs are decreasing, meaning that every additional unit of production costs less than the previous one. After reaching certain level of quantity, the marginal costs are rising – every additional unit is more costly. The average variable costs are decreasing at low quantity levels but after reaching a level where AVC = MC, they start to rise. As a result of that, we can infer that until reaching a certain level of production amount one unit of production costs less and less. When MC > AVC, average variable costs start to rise.

3.2 Supply side economies of scale

Economies of scale are a microeconomic phenomenon that can be explained by better operational efficiencies within a company as its production grows larger. With growing number of units produced, the costs for producing one unit are decreasing. In this case, the costs are a decreasing function of quantity as depicted in Figure 3.3. The most common example to be found in the literature is natural monopoly, that exists in industries with high-fixed and zero or very low marginal costs.

Figure 3.3: Economies of scale



Source: author's drawings

In the information economy, these market structures often represent common practice. Farrell et al. (2004) mention that the solution to natural monopolies offered in many textbooks is government regulation. On the other hand, he also suspects regulation of offering its own inefficiencies and there are some good reasons why the social loss from the high-fixed cost, low-marginal-cost industries may be substantially less than is commonly believed. There are in his opinion two reasons for believing this:

- The textbook analysis assumes the existence of the monopoly when analyzing its behavior, but rarely examines why the monopoly actually exists. In addition, real-world competition is much more complex and dynamic than in economic theory.
- In the case when the biggest firm has the most favourable cost conditions, then a fierce competition to be the biggest player will take place on the market, pushing the prices down and therefore benefiting consumers. We can find many examples of this behavior in the real world.

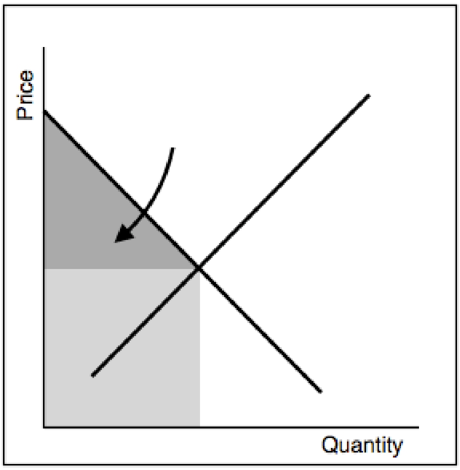
3.3 Price discrimination

In a standard textbook analysis of competitive markets we assume that companies sell their products for the same price. In reality this is very often not the case, though – companies try to charge different customers different prices. When analyzing price discrimination, we have to move out of the perfectly competitive market where the price discrimination would not be possible by assumption – in a competitive market, a lot of producers are selling identical product and are unable to influence the price in any way. Therefore, we have to assume non-zero market power for the agent to be able to conduct price discrimination techniques. Price discrimination is characterized by transferring the surplus from consumers to producers who are constrained by their market power and especially by the knowledge of consumers' behavior. The intensity of the constraints determines what portion of consumer surplus will be transferred to the hands of producers.

3.3.1 First-degree price discrimination

When a company disposes of monopoly power over the market, it can implement the purest form of price discrimination – so called first-degree or perfect price discrimination. It extracts all the consumer surplus as indicated in Figure 3.4 below.

Figure 3.4: First degree price discrimination



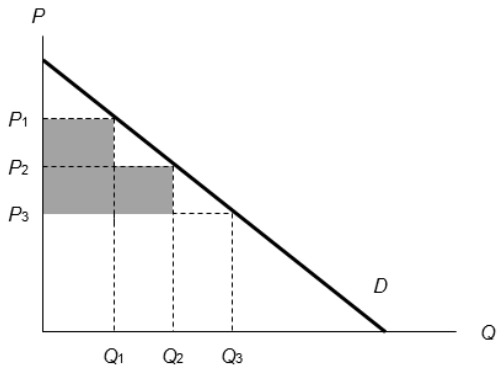
Source: author's drawings

Without the presence of price discrimination, the monopolistic company is selling at one price that exceeds marginal cost. Due to the fact, that some consumers are willing to pay for the product more than what is marginal cost for producing it but are not willing to accept this high price, part of the potential benefit from trade is not realized and represents the deadweight loss. Based on knowledge of consumers' behavior and especially their willingness to pay, a company can tailor its prices to different customers according to the value which they attribute to the good. This ideally means that all of the potential trade opportunities will be realized and the deadweight loss resulting from monopoly power will disappear – every customer buys the product for the price equivalent to his maximal willingness to pay. As has been already stated above, price discrimination can be conducted under the assumption of knowledge of consumer behavior.

3.3.2 Second-degree price discrimination

According to Farrell et al. (2004), this weaker form of price discrimination occurs when all the consumers are facing the same menu of prices for a set of related products. These techniques are also known as "product line pricing", "market segmentation" or "versioning". The intuition behind is similar to the previous example of first-degree price discrimination, the main difference is that the distribution of consumer tastes is used to create a product line rather than tastes of a concrete customer. By definition, this technique is not as efficient in extracting the consumer surplus but can be used in situations when consumer behavior cannot be observed in such detail, but still some of behavioral patterns are known. Following Figure 3.5 depicts the process.

Figure 3.5: Second-degree price discrimination

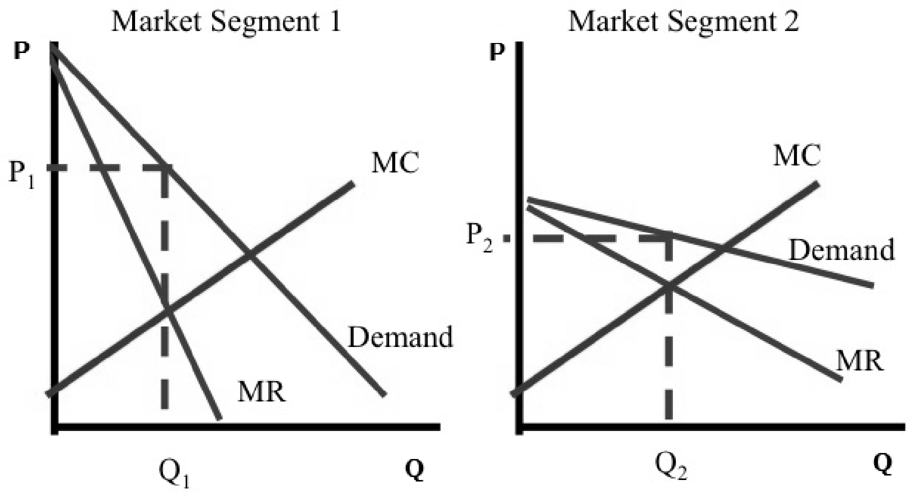


Source: author's drawings

3.3.3 Third-degree price discrimination

Third-degree price discrimination is a typical case and most widely-used form of charging different consumers with different prices. It is based on the mechanism that products are sold for different prices to various groups of customers. The analysis is often conducted on a monopoly case, but for example Armstrong and Vickers (2001) present a survey of literature that deals with competitive cases where third-degree price discrimination is present. According to Farrell et al. (2004), they even observe that when consumers have essentially the same tastes, and there is a fixed cost of servicing each consumer, then competitive third-degree price discrimination will generally make consumers better off, the reason being that competition forces firms to maximize consumer utility, and price discrimination gives them additional flexibility in dealing with the fixed costs. On the other hand, if there are no fixed costs, consumer utility falls with competitive third-degree price discrimination, even though overall surplus will still rise.

Figure 3.6: Third-degree price discrimination



Source: author's drawings

We can observe the mechanism of third-degree price discrimination on the Figure 3.6 in the non-competitive environment above. The figure is divided into two market segments that correspond to different target groups of consumers. Based on the observation of consumer behavior, the producer estimated the demand curve for both of the groups. The product is the same in both cases, so marginal costs of production are the same. In order to find optimal produced amount, we have to find marginal rent curve which is determined by the demand curve – therefore it differs across the segments. The demand curve in turn determines the marginal rent curve and according to the golden rule principle where MR = MC, we can find optimal amounts Q_1 and Q_2

3.4 Switching costs and lock-in

Classical economics assumes that when a market is driven out of the equilibrium due to some shock, forces of supply and demand interact and determine new equilibrium market price and quantity. If this mechanism does not work at all or at least does not work properly, the market exhibits inefficiency of a certain degree. The presence of information technologies and especially their impact on the pace of information transmission among markets scattered around the world was expected to enhance the efficiency of markets in general. This is intuitive and can be demonstrated easily in the example that follows.

3.4.1 Simple information transmission example

Let us assume a market **M1** for a tradable commodity **A**. The market is observed under two different states of the world - industrial age, and information age, denoted **S1** and **S2**, respectively. In each of these, the speed of information transmission, denoted by **V**, follows the relationship:

$$\boldsymbol{V_{S1} = 2\, V_{S2}} \tag{3.7}$$

The equilibrium condition under both states of the world says that quantity demanded equals quantity supplied. Suppose that the market is in the equilibrium and is, all of a sudden, affected by a negative demand shock. The supply starts to adjust the demand and the price mechanism works towards reaching the new equilibrium both in the industrial and information age. The crucial difference is observed in the speed of this accommodation process. Since in the information age, the information flows among the market participants twice as fast as in the industrial age, in the information age, it takes the market half of the time to reach the new equilibrium in comparison with the state **S1**.

3.4.2 General characteristics

Having admitted that information technologies facilitate trade and make the adjustment processes of supply and demand faster, we still cannot say that the New economy is in general more efficient and totally frictionless. This is mainly because the consumption function of the customers is affected by another variable. As indicated in Fuchs (2011), an agreement can be made that the Internet makes consumption easier than ever meaning that consumers do not have to drive to the store to order a new computer, but their choices for the future will still be hemmed in by the selections they made in the past.

We can illustrate the basic intuition using a simple analytics introduced in Farrell and Varian (2004), where in the economy there are n consumers willing to pay $\boldsymbol{v}$ amount per period to buy a non-durable good, while the good is produced by two companies at a constant marginal cost of $\boldsymbol{c}$. If a consumer wants to change consumption from one producer to another, he faces switching cost of $\boldsymbol{s}$. The author supposes $\mathbf{v} \geq \mathbf{c}$ but $\mathbf{v} + \mathbf{s} < c$, implying that it pays off the customer to purchase the good but not to switch the producer. In this case, we can find a unique Nash equilibrium in the second period of price $\boldsymbol{v}$ which is to be set by both of the producers, thus realizing profit of $\mathbf{v} - \mathbf{c}$. The sellers can realize this profit due to the fact that the customers are locked in their positions towards the producers since none of these sellers are able to offer sufficiently low price as an incentive to change the supplier

From the point of view of the switching costs, the situation can be even worse when we undertake an investment into durable goods and simultaneously do not rule out the possibility of complements purchases in the future. On one hand, in such situation the suppliers will be highly motivated to provide you with the durable good, since, as Farrell and Varian (2004) suggest, once the customers are locked in, they can be a substantial source of profit. An investment into a technology infrastructure supplied by one company can effectively lock the agent in the position for many years to come. The greater the value the first purchase has, the stronger the lock-in effect is. The same applies for the estimated economic life of the asset. If the asset depreciates slowly, an agent is effectively locked in his position for purchases of complements. This effect can be diminished if there is a market for used assets of this kind where an agent can retrieve a substantial part of its initial investment. Next aspect that also contributes to the lock-in effect is the risk of the operational failures in the transition phase towards the new supplier. In other words, generally speaking, lock-in function of an agent is increasing with the amount of the initial investment, increasing in the economic life of the asset and increasing with the growing risk of operational failures as well.

From the market point of view, there is no difference whether the switching costs affect one agent which is the only consumer in the market or thousands of consumers, each of whom constitutes only a fraction of the demand for products of the supplier. The crucial point when dealing with lock-in is to provide per customer basis evaluation. It is, therefore, irrelevant if the customer base is built up of thousands of customers with very low switching costs on an individual level or one big customer with significant switching costs. In both of the cases we can state that switching costs pose barriers to entry and they are, therefore, under constant surveillance of regulatory authorities which aim to diminish the switching costs present in the market to low levels to foster competition.

Even the information transfer in the New Economy can be viewed from the point of the switching costs. Studies, among others Sutherland-Smith (2002), have documented that people do not read Web content the way they read paper content – they are very fickle and when their interest is lost, so is their presence. This is based on ergonomic reasons on one hand, but, perhaps more importantly, on the fact that picking up another book or newspaper involves switching costs whereas on the web one click is sufficient to move forward to another source of information.

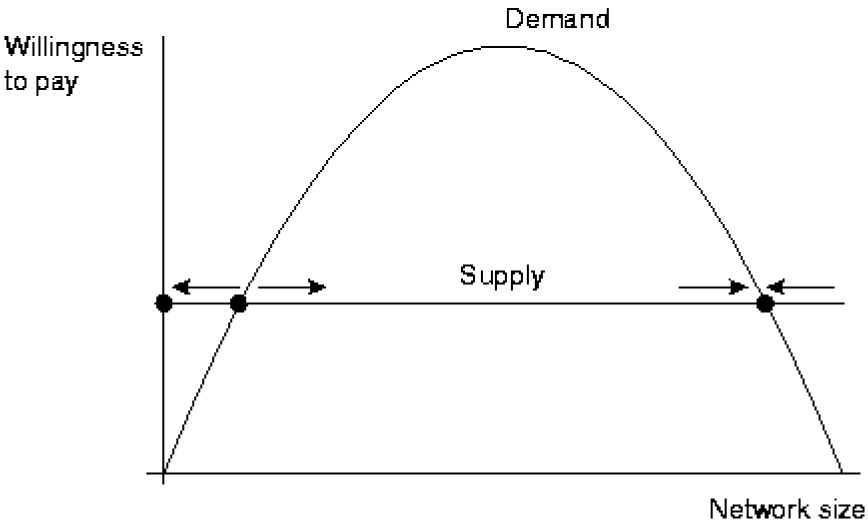
3.5 Network effects

For much of the second half of the 20th century, the industry sectors were dominated by oligopoly structures. The markets were, therefore, relatively stable, growing and shrinking only occasionally without some major deviations. In the new economy, technology companies are striving for dominance in the market because its obvious for them that sooner or later their technology will become obsolete and will be substituted by a technologically superior product or service. In the industrial economy, the fundamental characteristic of the system were economies of scale. The larger the share captured in the market, the bigger was the utilization rate of the factories, the smaller were the unit costs and the bigger the profit was. In the new economy, the markets are driven predominantly by network economies, i.e. network effects.

This phenomenon is not recent. The tendencies to take advantage of the networks were apparent in the transportation and communications industry even in the industrial age. Companies were striving to connect to another network in order to significantly raise their own value.

The number of people connected to a network is determining its value. Alternatively, the demand for a good (network) is directly influenced by the amount of buyers that are already part of it. It is, therefore, better to be connected to a larger network than to a smaller one. The key effect present in the new economy is the positive feedback – a product or service A provides incentives to buy a product or service B which in turn again provides incentives to buy product A. This feedback loop causes the variable (product A) to grow indefinitely. In some contexts, this is called unstable behavior and is undesirable. However, in other contexts, such as biological and economic growth, this is very desirable (at least for some part of the trajectory) [Kim et al. (2000)]. Following figure taken from Farrell et al. (2004) depicts a supply-demand diagram for a network good.

Figure 3.7: Network effects



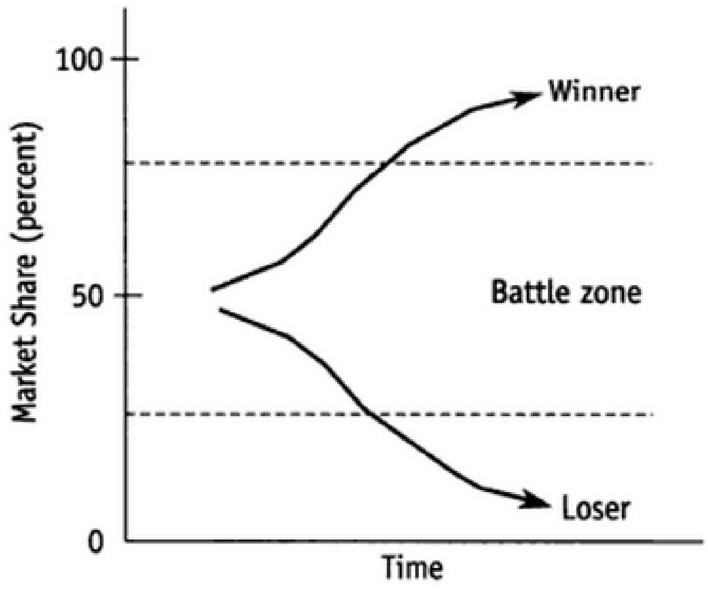
Source: Farrell et al. (2004)

This is a model with a perfectly elastic supply curve where the price for the product is constant, independent of the size of the network. The typical hump shape of the demand curve can be explained using two phases. In the first phase, the marginal willingness of the consumers to pay is increasing with every new entrant to the network, e.g. every sold fax machine. The second phase exhibits typical market effects of reaching customers with gradually lower and lower willingness to pay. This system consists of three different equilibria, the three points depicted in the figure. The arrows suggest which one is dynamically stable (the first and the third one) and which is dynamically unstable.

Consider, for example, the market situation when the network is in early stages of its development and size, thus no network incentives are luring customers and the price for the product is higher than what is the market willing to pay. Unless there is some shock from the outside, the network is slowly doomed to failure since nobody is willing to pay the price to be a part of a network with him as the only member. Suppose, on the other hand, that the manufacturer knows about these effects and temporarily cuts prices to lure customers under the price that they are willing to pay. The supply line drops and markets starts buying the goods. If that is the case and the manufacturer raises the prices again, while now, because of network effects, is customers' willingness to pay equal to the price, the market reaches its critical mass. At this point in time, positive feedback effects set in, making this equilibrium unstable. The network is getting larger till it reaches its third equilibrium level. This is stable since all of the customers with the willingness to pay equal or higher than is the price have already purchased the product and there is no motivation anymore for the manufacturer to cut the price.

By no means should be the positive feedback mistaken for growth. The same effects that act in favour of one firm are negatively affecting the company on the other side of the spectrum and the dynamics are identical. It is often just a matter of bad luck and coincidence. The good example of that is personal computer operating systems market of the 1990s where Apple Macintosh suffered a painful defeat by Wintel establishment, formed from Intel as a manufacturer of computer hardware and Windows as the operating system. Following Figure 3.8 firstly introduced by Shapiro and Varian (1999) depicts the dynamics of the process.

Figure 3.8: Market share dynamics – network effects



Source: Shapiro and Varian (1999)

Horizontal axis captures time, vertical market share of the firm in percent. At time t at the beginning of both trajectories the market shares are almost evenly split - Winner controls, say, 55 percent of the market, whereas the Loser has captured 45 percent of the market as of time t. For some reason the Winner gains additional 5 percent of the share. This lures even more customers to Winner's product due to the positive feedback effect since all of the users want to join the winning part, ensuring that their purchase will preserve value in the future. Over time, it is very likely that Winner dominates the market. The declining trend in the market share of the Loser is unavoidable since negative feedback effect set the Loser on the vicious circle path already.

4 A company and IT in the information economy

Estimating the influence on business is a pretty challenging quest and as a result of that, the results of the studies often differ. In order to be able to assess the impact of IT on firm's performance (profitability, value-added measures) it is necessary to take a closer look at the three relevant factors:

- microeconomic theory, i.e. its applications in the information economy
- information technology, i.e. its use in business practice
- business strategy in IT environment

4.1 Microeconomic theory in the new economy

The aim of microeconomics as a research field is to study the interactions between the economic agents. Apart from other subjects, it analyzes market structures that offer the firms possibilities of taking advantage of its position in the market at the expense of others. These structures of imperfect competition emerged based on one of the below mentioned factors:

- barriers to enter the industry for the possible new entrants
- number of companies operating in the market
- type of product/service that the firm produces
- information that is known to one or a limited number of agents

The more the industry resembles the perfect competition structure known from the textbooks, the more is it feasible and reasonable for the companies to deviate from the common use of information for the production and administrative purposes and to use it as a marketing instrument. A long-term profitability of IT-related improvements is very difficult to sustain unless a company operates a sophisticated and complex system that is prohibitively expensive for the rest of the market.

When attempting to analyze production of a modern company in the new economy, the production function in recent research mostly looks, according to Diwan and Kudyba (2003), as follows:

$$Q = f\ (L, K, ItK) \qquad (4.1)$$

In this equation, L stands for the total amount of labour employed in the production, K is for the total amount of capital utilized in the production and ItK for the total amount of information technology capital. The use of IT is not limited to assist in the production to make the production processes more efficient, but information technologies are also useful, as already indicated above, for the promotion and marketing purposes. Therefore, the production function is further divided to:

- $S = (L, IK)$, where L stands for the labour engaged in customer service and IT for IT capital engaged in customer service
- $M = (L, IK)$, where L stands for the labour engaged in marketing activities and the same applies for IT capital

The function of the demand for firm's products can be, thus, defined as follows:

$$Q_d = f\ (P, S, M, P_{ind}, S_{ind}, M_{ind}) \tag{4.2}$$

where:

P	price of the good set by the company
S	customer service activities
M	marketing activities
P_{ind}	average price of the good in the industry
S_{ind}	customer service activities on average in the industry
M_{ind}	marketing activities on average in the industry

The first variable that influences the demanded quantity is the price set by the company. According to the law of demand, the quantity demanded is inversely related to the price. The second factor in question is the amount of labour and capital employed in servicing customers and for the marketing purposes. The increase in both of them raises the quantity demanded by the market. The company also has to deal with the same factors from the external side. Industry price on the market in comparison with the company's price plays a crucial role when determining the demand for the goods produced by the company; the same applies for customer service and marketing activities conducted on average in the industry.

Apart from the above-mentioned tangible factors, a firm's demand function is also dependent on the intangible ones, such as brand recognition and brand name. The elasticity of the demand for the firm's brand is a crucial factor here. If it is significant, a firm can invest into marketing, thus creating a monopoly power and set the price above its marginal costs. This effect would be only temporary, though, since the price of the marketing activities based on technology is declining. If a company realizes such an advantage, the competing companies will do their best to diminish it and they are bound to be successful in the longer run.

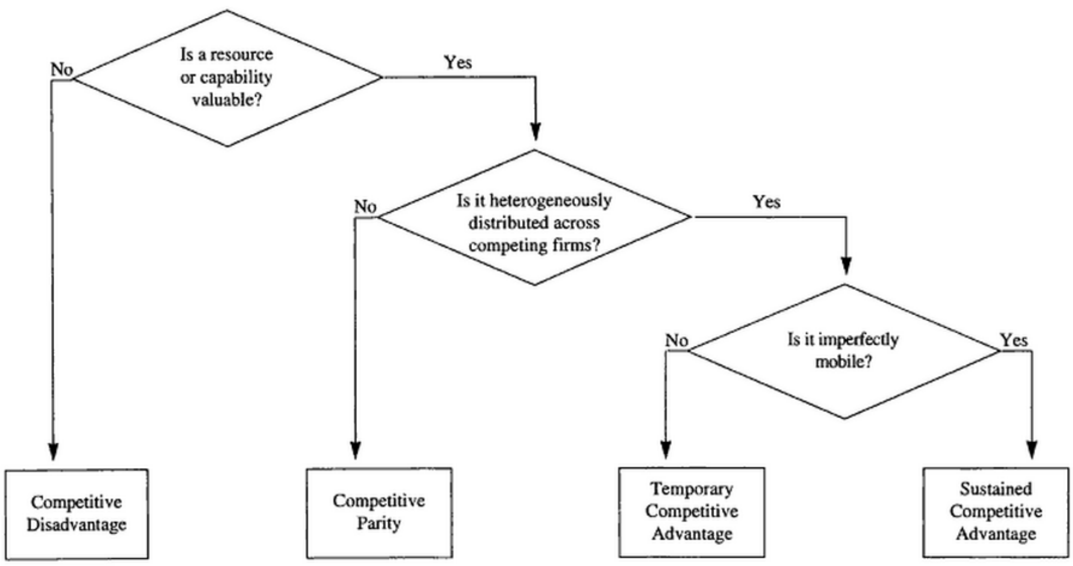
In a competitive environment it is impossible to realize abnormal profits for a longer term. According to economic theory, a firm should earn as much profit to be able to cover all the production-related expenses and provide a reasonable compensation for the owner. The degree of competitiveness in the industry is inversely related to firm's ability to generate abnormal profits. One way to achieve that favourable position is to find ways to prevent potential competitors from entering the market, thus avoiding the pressures to decrease the price level in the industry. Apart from these barriers, product differentiation and patents may be a decisive factor when aiming for preserving the abnormal profitability in the future. The relationship between the long-term abnormal profits and information technology investment raises questions if the utilization of IT in the firm can raise profitability over the long run.

The usage of networks in the late 20th century was unprecedented. The technology allowed to gather information about the customers and production, to store it and consequently to create strategies for the improvements in efficiency. These networks have a large intrinsic value for the firm managers, they make observing the purchasing behavior of customers possible and enable them, therefore, to identify customers' needs and consequently to better allocate production. In large companies, this may be the source for large economies throughout the whole production and selling process. Moreover, these large companies enjoy the economies of scale from buying the inputs from the suppliers in great amounts and operating in more countries simultaneously. The combination of economies of scale in production and usage of information technology networks to make the production leaner, more efficient and more customer-oriented may create barriers for entry and the large companies may therefore preserve the abnormal profitability over the long term.

4.2 Competitive edge in the new economy

The key to success is to find an advantage that is able to persist in the firm's arsenal over the long term. In general, Barney et al. (1995) suggested that a firm has a sustained competitive advantage when it is implementing a strategy not simultaneously implemented by the competitors and where the competitors face significant disadvantages when acquiring the resources necessary to implement this strategy. Put differently, a competitive advantage can be created with the use of information technology if the crucial resources are distributed heterogeneously in the industry and in the case of their immobility. The figure 4.1 from Barney et al. (1995) depicts the criteria for a sustained competitive advantage.

Figure 4.1: A resource-based model of competitive advantage



Source: Barney et al. (1995)

Factors leading to resource immobility are mentioned:

- the role of history,
- causal ambiguity,

A firm can imitate another firm's resources and capabilities at a low cost only if the imitating firm knows what it is about the successful firm that should be imitated. When there is causal ambiguity about the source of the competitive advantage, imitation becomes more costly. [Barney et al. (1995)]

- and social complexity.

When applying this theory on the information technology, Diwan and Kudyba (2003) and Barney et al. (1995) identify the factors which have the potential to create and to preserve the competitive advantage developed by IT as the following ones:

1. **Access to capital**

The barriers in a given industry can hardly provide the ground for creating the sustained competitive edge since they are similar for each firm. The only solution may be a very sophisticated infrastructure that is rentable at very high quantities of production.

2. **Proprietary technology**

The workforce mobility of IT staff and related information exchange prevents firms from realizing long-term competitive advantage based on proprietary technology. Moreover, competitors are implementing reverse engineering policies, i.e. buying processing software from a company and decomposing it to find the root of the algorithms.

3. **Technical IT skills**

Programming languages knowledge is homogenously dispersed in the industry and even if it was not the case, the workforce mobility will leave any efforts of making technical IT skills as a sustained competitive advantage meaningless.

4. **Managerial IT skills**

Information technology is used to support various functional areas and divisions in a firm. Managerial IT skills correspond to creating a complex network within a company utilizing learning-by-doing method. This network corresponds to long-term cooperation within the firm and is based on social interactions among the managers. This method is, therefore, not transparent and very hard to imitate. The social structures in the industry differ from one firm to another and as a result of that, this source of competitive advantage is immobile and may constitute, according to research, a long-term competitive edge.

4.3 Information technology and labour

Many studies suggest that IT investments themselves are not sufficient and that they are complemented by changes in the company's employment structure. Michaels et al. (2014) for example hypothesized that information and communication technologies (ICT) polarize labour markets by increasing the demand for the highly educated at the expense of the middle educated, with little effect on low-educated workers. In this study, their hypothesis proved correct as technology accounted for up to a quarter of the growth in demand for highly educated workers during 1980-1999. Similar conclusions were made by Bartel et al. (2007). Another work of David and Dorn (2013) confirms the hypothesis that sophisticated technology has made some manual and cognitive jobs obsolete, suggesting that the local labour markets that specialized in routine tasks reallocated low-skill labour into service occupations (employment polarization) as a result of information technology adoption.

Other studies of the labour market and information technology focus on the productivity of so-called information workers, i.e. workforce that interacts with technology on a daily basis[1]. Aral et al. (2012) assessed whether the knowledge accessed by the workers through their electronic communication networks enabled them to multitask more productively. They conclude that IT-induced multitasking is indeed related to a higher project output[2]. Figure 4.2 depicts the distribution of average annual percent change in productivity in the United States. According to Bureau of Labor Statistics (2014), during the years 1987-2012 the productivity rose in all industries apart from one while the hours

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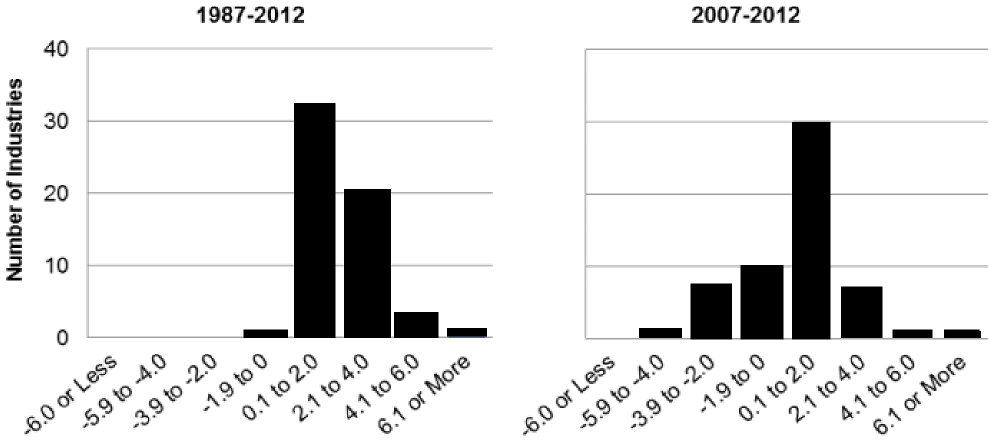
[1] Not necessarily in a sophisticated manner – information worker is an equivalent for a regular office workers.

[2] Subject to diminishing returns, though.

worked increased in a very few of them. The same pattern is apparent in majority of the industries which is supporting the research and its results named above.

Figure 4.2: Distribution of average annual % change in labour productivity



Source: Bureau of Labor Statistics (2014)

4.4 Information technology in selected industries

The proliferation of information technology into the economy differs from industry to industry and following paragraphs will provide the reasons for their utilization in finance and insurance, manufacturing, retail, mining and utilities sectors.

Finance and insurance industry consists of investment banks, commercial banks, brokerage firms and consumer loan institutions. Their nature differs and so do their needs. In general, they use IT for communicating between branches and divisions, customer-oriented service along with the analysis of customers and the market to ensure that their pricing policy is reasonable. The credit institutions, on the contrary, use information technologies for gathering as much data about the customer as needed in order to be able to target his needs and, maybe more importantly, avoid risky transactions. This saves money otherwise spent on unreasonable campaigns and lost when providing credit to a low-rated customer. Commercial banks predominantly use IT to cut the amount of fixed assets at their disposal, since the automated technology enables them to use automated machines instead of labour force situated in large buildings. Investment banking is able to instantly close the security deals trading all over the world, while insurers enjoy the features of information technology when dealing with the claims of the clients.

Recent studies have shown that investing in information technology is still a worthwhile strategy when striving for the improvement of the profitability. For example the study of Gatawa et al. (2013) study of the Nigerian banking industry suggests that the higher use of ICT increases the return on equity. Without simultaneously implementing corresponding strategies on a branch level, the benefits of investment in technology are not fully exploited, though. On this account, Ali Azadeh et al. (2009) empirically tested the information technology’s impact on bank performance and concluded that IT investment appears to have a stronger positive impact on bank performance in presence of greater environmental changes and more proactive branch strategy. Therefore, banks considering IT investment should assess their environmental contexts and strategic directions. Analogical conclusions were found in the above-cited work of Gatawa et al. (2013). Specifically, they have revealed an inverse relationship between additional sustained investment in ICT and efficiency, therefore suggesting putting more emphasis on policies that will boost efficient/proper utilization of ICT equipment rather than additional investments.

In manufacturing industry, information technology is predominantly used for streamlining the production and related operations. Earlier the manufacturers operated their own tailor-made systems in production, now they switched to standard enterprise resource planning systems because of their ability to foster integration of all the functional units. Manufacturer’s current goal is to enhance the communication among the customers, retailers, distributors and production lines while simultaneously keeping track of the global demand and capacity. Empirical evidence of the relationship of IT and the increased performance of the companies in manufacturing industry reached similar conclusions. Misra and Tewari (2012) identified in their study of manufacturing industry in India a strong positive relationship between IT usage, operational leadership and marketing efficiency. Similarly, Bayo-Moriones et al. (2013) conducted an empirical work on the data from a sample of 267 Spanish manufacturing SMEs and found the same relationship between information technology and all measures of company’s performance. Moreover, according to them, manufacturing companies benefit from IT mainly indirectly through the improvement of internal and external communication, as well as through increased operational performance, while the impact is not immediate and lag effects differ from one type of IT to another. Information technology may even improve the efficiency of all stages of the production process with reductions in setup times supporting the change in business strategy. [Bartel et al. (2007)]. On the other hand, in contradiction to the studies named above, recently released work of Acemoglu et al. (2014) identified little differential productivity growth in IT-intensive manufacturing industries. According to them, when some productivity growth can be identified in the data, it is at the expense of the declining employment. Finally, gross output does not even appear to grow faster in such industries than in the rest of the manufacturing.

Mining industry is an industry characterized by low margins. As a result, efficiency in production processes and keeping costs low is the key to success. According to Diwan and Kudyba (2003), overall investment of the industry in IT was among the lowest in the economy during the late 1990s but it started to rise after the year 2000.

The key factor in the retail industry is to make the customer experience as pleasant as possible. The electronic scanners provide simple and effective evidence of the flow of the goods, help to identify purchasing patterns of the customers and facilitate streamlining the order in the producer – wholesaler – retailer chain. A significant technological breakthrough for the retailing industry was provided by the on-line commerce, which was before the year 2000 almost non-existent.

The utility industry in the United States got deregulated towards the end of the 20th century, opening space for competition. Information technologies play key role in the fight for customers since creative utilization of IT may help in luring the customer. In utilities, data gathering about the customers is a daily work, as well as analyzing elasticity of the demand with respect to price changes. From the operational point of view, IT finds its use in power plants where it instantly reacts to changes in the demand for electric power.

4.5 Empirical research on IT and firm's performance

Based on the theoretical background provided on preceding pages, the recent empirical research on the topic of the relationship between IT and firm value-added will be discussed. The methodology used in this field of economic research varies to a large extent and it is often difficult to compare the results. The task may be even more difficult when the research is producing contradictory figures depending on what model and variables are taken into account and which data are used for the analysis.

4.5.1 Productivity paradox as the early stage

The earliest research on the topic of IT and firm's performance found only little evidence of the economic value of information technology that it was expected to bring to the economy. As Solow (1987) mentions in his famous article, researchers were somewhat embarrassed that everyone felt there was an IT revolution, yet no one was able to identify it empirically[3]. His quote *"You can see the computer age everywhere but in the productivity statistics"* precisely captures the state of the research those days.

Ten years later, one of the first studies to identify the productivity gains as a result of utilization of IT was provided by Brynjolfsson and Hitt (1996) in their empirical study of 370 companies where their production function estimates of the productivity of IT stock suggested a gross marginal product of nearly 95 percent, implying positive returns. On the other hand, when running the regression with profitability as the dependent variable, no evidence was found that IT use led to abnormal profits. They suggest it is caused by the increasing competition entering the market to exploit the profit opportunities stemming from IT utilization. According to them, information technology makes the production process more efficient, therefore reduces costs and increases profit margin. New entrants are lured into the industry, pushing the industry price level down. Other research confirms that the easier the technologies are to imitate and implement by the competitors, the more of the return of IT investments is passed to the customers, increasing their surplus and the less remains for the producers

[3] So-called „productivity paradox" firstly identified by Brynjolfsson (1993).

to enjoy increased profitability. Gullickson (1997) summarized that in the present highly competitive manufacturing environment, productivity growth represents the means by which the effects of input price increases may be mitigated. Put differently, these are the means by which payments to labour and owners of capital may rise without the increases being passed on to output prices.

4.5.2 Recent research on the topic

As indicated in the preceding paragraph, the research of mid-1990s has finally shed some light on the relationship between information technology and firm's productivity. Later on, the studies of early 2000s backed up the hypotheses of growing productivity. Among others, study of the data from the years 1995 – 1997 reported by Diwan and Kudyba (2003) indicates that IT can enhance firm-level profitability and that the modern era technology instruments augmented previously existing information technology. According to them, the added value of the sophisticated technology lies predominantly in the provision of advanced networks that facilitate the information flows.

The growth of the US productivity indeed surged throughout the years 1995-2000 and even after the dot-com crisis in 2000, reaching the post-war growth levels [Sadun and Van Reenen (2005)]. The rising productivity was not a worldwide trend present in the economy, though. To give an example, this was especially the case of Europe, which did not follow that pattern at all with its productivity growing only sluggishly. Researchers accepted the challenge to explain this phenomenon - for example Sadun and Van Reenen (2005) explained the differences between the productivity performance of information technology in Europe and in the United States based on the firm's organizational structure. He argued that US firms are simply better placed to take advantage of ICT and suggested that European firms will have to adopt more US style business processes to obtain the same level of productivity advances. For the less developed parts of the world, Lang and Hawash (2010) tested whether higher IT adoption leads to higher productivity over the period 2002-2006 on the sample of 33 countries. This was proven true and IT adoption was identified as one of the most significant factors contributing to growth of total factor productivity in the developing countries.

One common trait of the state-of-the-art research on the topic is the successfully verified hypothesis that information technology improves firm's productivity. The use of IT itself cannot account for all of the productivity growth, though. The related implementation processes and changes in organizational aspects of the firm [Sadun and Van Reenen (2005)] are a necessary complement in the pursuit of higher productivity and performance. The adoption of IT often even alters business strategies, as Bartel et al. (2007) suggest-.

5 IT impact on firm's value added: an empirical analysis

Since late 1970s, the microprocessor technology has been steadily improving. As a result of that, personal computers slowly became a standard in the business economy. They were becoming much easier to use, significantly smaller than they used to be and more powerful. Throughout all industries, the presence of IT was noticeable. Table 5.1 which follows describe the growing proportion of IT investment. In the year 1999 the share of investments in information technology reached almost a half of the total investments allocated to industrial equipment and software.

Table 5.1: Share of IT investments on total investments

	Investment in IT as a proportion of total investment in Industrial equipment and software; (%)
1980	30,7
1990	39,1
1999	47,2

Source: Council of Economic Advisors (2001)

Simultaneously, communication technologies have been in the process of constant improvement as well. New inventions, such as wireless technology and fiber optics have made new communication instruments possible. Treated separately, both computer and communication technology have meant a major breakthrough for business. The complementary nature of these, though, has been the most significant aspect. It is the convergence of the computer and communication technologies that enabled the computer to become a mean of communication of daily use and enabled digital data to be transmitted via sophisticated networks. Influence of these complements on the industries and economy as a whole is unquestionable and to find out more on this topic, many recent papers have posed the question –how do computer and communication technologies enhance efficiency, performance and structure of the businesses?

Besides workforce, value-added depends on capital. The absolute value of capital is not much relevant, though, its efficiency is much more important. Towards the end of 1990s, as Jorgenson (2001) mentions, the stock of all IT assets combined accounted for only 4,35 percent of domestic tangible capital stock in the US in 1990.

To define the efficiency of capital Jorgenson (2001) recognizes the main difference between growth in capital services and capital stock as the improvement in capital quality. On a firm level it implies a substitution towards assets with higher marginal products. The same absolute value of capital in the year *y* and *y+5* may, *ceteris paribus*, generate very different value-added. Numerically speaking, the total growth of capital quality in the years 1948-1995 was 20 percent. Moreover, this growth increased two-fold in the 1995-1999 timeframe.

5.1 Hypotheses

- <u>Hypothesis #1: The growing proportion of IT assets in total assets is related to higher value-added in the economy.</u>

Based on the research in this field and a higher marginal productivity of IT assets it shall be hypothesized that the growing proportion of IT assets within total assets will improve the productivity of assets in total a therefore firm’s value-added.

- <u>Hypothesis #2: The impact of IT on value-added differs significantly among the industries.</u>

On aggregate economy level it is assumed that a growing proportion of information technology assets boosts value-added. This does not necessarily apply for a comparison of separate industries. Therefore differences among the impacts on value-added are expected.

- <u>Hypothesis #3: The size of a firm prior to IT boom is a significant factor when assessing the impacts of IT on the value-added.</u>

Research papers, for example Beede and Montes (1997) suggest that the influence of IT on firms depends on their size prior to IT revolution. This topic will be discussed in the last part of the thesis.

5.2 Data

The main source of the data for the analysis of 19 US industries is the US Bureau of Economic Analysis and its online accessible Gross-Domestic-Product-(GDP)-by-Industry data with the value-added statistics by industries categorized in North American Industry Classification System (NAICS). This categorization was presented by Federal statistical agencies in classifying business establishments for the purposes of collecting, analyzing, and publishing statistical data related to the U.S. business economy. [US Bureau of Census (2014b)] The data for total assets were gathered from Fixed assets and consumer durable goods 1997-2010 and 2003-2013 tables. [(Bureau of Economic Analysis (2011, 2013)] Total annual payroll data for the industries were gathered in the County Business Patterns reports provided by US Bureau of Census [US Bureau of Census (2014a)].

Information technology assets are determined based on the expanded data collection version of Annual Capital Expenditures Survey (ACES). The capital stock data for the industries are available in every year's ACES. Detailed asset type shares are developed for the year following Economic Census conducted by

US Bureau of Census[4], i.e. 1998, 2003, 2008, 2012, using special tabulations of the expanded ACES and the ICT survey, supplemented by other source data to resolve coverage issues. The proportion of the IT assets for the years 1999-2002, 2004-2007 and 2009-2011 is approximated by the ratio of IT to total assets in the years 1998, 2003, 2008, 2012. This is done in accordance with Bureau of Economic Analysis's (1993) findings that allocations of specific categories of capital flows do not change much over time and therefore their slight hypothetical change during the non-observed years should have negligible impact on the estimated parameters in the model.

The relatively short time series of data, spanning only 15 periods (years), on the other hand, could be an issue that has to be taken into account when interpreting the results. The length of the series is constrained by the year 1998, as this was the year when NAICS statistical framework was introduced. Before NAICS, data for the industries were gathered in the framework of SIC (Standard Industrial Classification). Since both of these are incomparable and both US Bureau of Census and US Bureau of Economic Analysis have undergone the change of framework from the SIC to the NAICS, it is almost impossible to obtain relevant and comparable data for the years before the NAICS system. The limited time frame of the study cannot be neglected when the regression parameters will be interpreted.

5.3 Methodology

This study investigates the influence of information technology assets proportion of total assets on firm's value-added in the years 1998-2012. The relationships are observed on the level of industries, based on which firm-level implications are inferred. The crucial assumption imposed on the model is that industry-level changes demonstrate to a large extent the trends that predominate on the lowest level, although not precisely. The regression coefficients, therefore, have to be interpreted with caution.

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[4] The Economic Census is the U.S. Government's official five-year measure of American business and the economy. It is conducted by the U.S. Census Bureau, and response is required by law. [US Bureau of Census (2014)]

Value-added is the dependent variable specified in logarithm[5.] . The model resembles the ones earlier used by Berndt et al. (1992) and Beede and Montes (1997) in their studies of information technology's impact, controlling for the capital intensity of production in order to be able to capture the effect of changes in composition, but not the level of capital stock. It consists of the following variables:

- Dependent variable: ln_VA: Industry value-added

  The value-added variable in the model enters the model as logarithm. It is defined by Bureau of Economic analysis as a contribution of a private industry or government sector to overall GDP. The components of value-added consist of compensation of employees, taxes on production and imports less subsidies, and gross operating surplus. Value-added equals the difference between an industry's gross output and the cost of its intermediate inputs for a given industry in a given year.

- ln_KL: Ratio of the total fixed assets and total annual payroll

  Based on Bureau of Economic Analysis (2011,2013) and time series for total fixed assets in the industries with relation to GDP and industry annual payroll data reported in yearly County Business Patterns reports by U.S. Bureau of Census (2014a).

- ln_ITtotalcap: Share of IT capital in total capital

  Due to the limited access to data of the level of IT capital on the industry level and the absence of clear guidelines for the definition, the study uses similar specification as Berndt et al. (1992) and Beede and Montes (1997) used in their analysis. IT capital encompasses computer and peripheral equipment, software, communication equipment, instrument, photocopy and related equipment and office and accounting equipment.

The multiple regression model for industry value-added looks as follows:

$$\text{ln\_VA} = \beta + \beta 1 \ln\_KL + \beta 2 \ln \ln\_ITtotalCAP + \in \quad (5.1)$$

[5] Logarithm specification implies treating this variable as the elasticity, i.e. coefficient of 0,05 suggests that a 10 percent increase in the variable, *ceteris paribus*, results in an 0,5 percent increase in the dependent variable, the value-added in this case

5.4 Empirical results

Following pages are devoted to the actual regression analysis using methods of multiple regression and panel data analysis. The software used is Stata. The basic features of the dataset can be found Table 5.2 below.

Table 5.2: Basic features of the dataset

```
Industry:  11, 21, ..., 81                                      n =        19
    Year:  1998, 1999, ..., 2012                                T =        15
           Delta(Year) = 1 unit
           Span(Year)  = 15 periods
           (Industry*Year uniquely identifies each observation)

Distribution of T_i:   min      5%      25%      50%      75%      95%     max
                        15      15       15       15       15       15      15

     Freq.  Percent    Cum. |  Pattern
 ---------------------------+-----------------
       19    100.00  100.00 |  111111111111111
 ---------------------------+-----------------
       19    100.00         |  XXXXXXXXXXXXXXX
```

Source: Stata; author's analysis

5.4.1 Pooled OLS

Firstly, the first estimation method will allow us to ignore panel characteristics of the data gathered, taking all the data from cross-sectional and time dimension and grouping them into a stream of individually observed cases.

Pooled OLS usually results in more efficient parameters since it allows for a richer source of variation. [Baltagi (2002)]. Simultaneously, it can generate biased estimates as there supposedly are different impacts of IT on the industries. Bearing this in mind, the first pooled OLS regression was run. A time trend variable was added to capture the effects that were not explicitly taken into account, such as socioeconomic changes. Following results were obtained:

Table 5.3: Value-added Pooled Time Series Regression, 1998-2012

Independent variables		Regression
IT share of fixed assets	β	0,235
	t-statistic	3,79
Capital intensity of production	β	0,02
	t-statistic	0,48
Time trend	β	0,05
	t-statistic	4,24
Constant	β	6,14
	t-statistic	42,01
Adjusted R^2		0,117

Source: Stata; author's analysis

As the Adjusted R^2 figure suggests, only a small fraction (11,7 percent) of total variation in value-added was explained using this regression. Capital intensity of production exhibits positive relationship to value-added, as per 10 percent increase in capital intensity, the value-added goes up by 2,3 percent. The hypothesis of its insignificance was not rejected based on the t-statistic. The significant coefficient for IT of 0,235 implies that a 10 percent increase in IT share is related to a 2,35 percent growth in value-added.

5.4.1.1 Breusch-Pagan test for heteroskedasticity

One of the basic assumptions of the OLS is constant variance (homoskedasticity) of disturbances. Ordinary least squares estimator is not, therefore, the best linear unbiased estimator if there is heteroskedasticity present in the data.

For the purposes of testing the presence of heteroskedasticity, Breusch-Pagan test was chosen. It is based on a set of disturbances obtained from the fitted model - $\hat{u}$. OLS regression constrains their mean to be zero. Given this assumption of independence of disturbances on explanatory variables, the estimate of the variance can be computed using the average of the squared values of the residuals. If this assumption is false, however, the true model exhibits a linear relationship of variance of disturbances to independent variables. as the basis for Breusch-Pagan test serves the regression of squared residuals on the explanatory variables.

The BP-test is a chi-squared test with k degrees of freedom. It tests the null hypothesis of no heteroskedasticity against the alternative one that hypotheses its presence in the data. The figure 5.1 below shows that the Breusch-Pagan test did not find any evidence against the null hypothesis. The hypothesis of homoskedastic data cannot be rejected. Pooled OLS run on this dataset is, therefore, supposed to be BLUE, at least as far as the assumption of constant variance of disturbances is concerned.

Figure 5.1: Breusch-Pagan test for heteroskedasticity

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_VA

         chi2(1)      =     0.05
         Prob > chi2  =   0.8241
```

Source: Stata; author's analysis

5.4.1.2 Chow test for the stability of the coefficients

As already indicated, pooling the data is appropriate only when the homogeneity hypothesis can be confirmed, i.e. when the impact of IT is the same across industries. The poolability test, Chow test, examines if panel data are poolable so that the slopes of regressors are the same across individual entities or time periods. If the null hypothesis of poolability is rejected, individual industries may exhibit different slopes of regressors and pooling the data will severely bias the coefficients. [Baltagi(2002)]. The Chow test statistic follows:

$$F = \frac{SSE_{pool} - (\sum SSE_{sep}) \,/\, (k)}{(\sum SSE_{sep}) \,/\, (\sum N_{sep} - 2k)} \sim F\,(k, \sum N_{sep} - 2k) \qquad (5.2)$$

where:

SSE_{pool}	Sum of squared residuals of the pooled OLS
SSE_{sep}	Sum of squared residuals of a separate regression
N_{sep}	Number of observations in the separate regression
k	Number of regressors (estimated coefficients)

In this step, a pooled OLS was run and its sum of squared residuals recorded. Consequently, 19 separate industry regressions were run with the same goal. Plugging the numbers in the expression for the Chow test, 4 coefficients are estimated (k=4) and total number of observations ΣN_{sep} is 285 (19 industries during 15 years). Corresponding values of sum of squared residuals of the pooled and separate industry regressions were taken into account as well and the F-test gave the value of 4999,16. Therefore, the hypothesis of no differences across the industries was strongly rejected on any confidence level, suggesting that the pooled OLS coefficients are biased.[6]

5.4.2 Panel data analysis

The results obtained and the tests run in the preceding section further strengthened the hypothesis that the coefficient estimates might differ industry-wise and that the estimates are likely to be biased. Based on this result, the right approach seemed to be to run separate regressions for individual cross-sectional units, industries. Before moving on, though, a panel data analysis was run to confirm the hypothesis. Its *raison d' être* is to identify and estimate the particularities and effects that are not detectable when focusing exclusively either on the cross-section or time series. According to Baltagi (2002), panel data sets allow the study of complex dynamic behavior and evolution of variables.

5.4.2.1 Wooldridge test for panel serial correlation

Linear panel-data models exhibiting serial correlation suffer from biased standard errors and their results are less efficient, therefore it is needed to identify serial correlation in the idiosyncratic error term.

Drukker (2003) has shown in his study that Wooldridge's test for serial correlation in one-way linear panel-data models can have good size and power properties in reasonable sized samples. In the presence of heteroskedasticity, though, larger sample sizes are needed to achieve reasonable relevance. Since the Breusch-Pagan test for the presence of heteroskedasticity could not reject the

[6] Obviously, this does not necessarily imply that subgroups could not be pooled if there is a relevant intuition behind it.

homoskedastic distribution of the disturbances in the dataset, Wooldridge test seemed to be a reasonable choice for detecting potential serial correlation.

Figure 5.2: Testing serial correlation

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,       18) =     59.419
           Prob > F =      0.0000
```

Source: Stata; author's analysis

The null hypothesis of the Wooldridge test assumes no first-order autocorrelation in panel data. As shown in the Figure 5.2 above, compelling evidence could be found against it and this hypothesis can be rejected on any confidence level.

5.4.2.2 Testing for stationarity

Having strongly rejected the hypothesis that no-first order autocorrelation is present in the data, the errors in this model are assumed to follow a first order autoregressive (AR1) process. In other words, the current error is part of the previous error plus a shock as indicated in the equation 5.3:

$$\text{AR(1):} \qquad \epsilon_t = \rho\epsilon_{t-1} + \upsilon_t \tag{5.3}$$

Now it is important to determine whether the mean, variance and auto-covariance structure do not change over time, i.e. whether the data exhibit so-called weak stationarity. Stationary series exhibits no periodic fluctuations (seasonality), no trend and has constant variance over time.

Researchers have introduced several unit root tests (tests for stationarity) with different asymptotic properties as their main factor of distiction [see Hlouskova and Wagner (2005) for a detailed overview]. With regard to the properties of the dataset at hand, where number of cross-sections is greater than the number of time periods, a decision was made to proceed with Harris-Tzavalis unit root test with the time trend included.[7] Test results can be found below in Figure 5.3.

[7] For this test, the number of panels is asymptotically growing to infinity and the number of periods is fixed.

Figure 5.3: Testing for stationarity

```
Harris-Tzavalis unit-root test for ln_VA
----------------------------------------
Ho: Panels contain unit roots             Number of panels  =     19
Ha: Panels are stationary                 Number of periods =     15

AR parameter: Common                      Asymptotics: N -> Infinity
Panel means:  Included                                 T Fixed
Time trend:   Included
------------------------------------------------------------------------
                    Statistic          z          p-value
------------------------------------------------------------------------
 rho                  0.3052       -4.1624        0.0000
------------------------------------------------------------------------
```

Source: Stata; author's analysis

The null hypothesis of the Harris-Tzavalis test is that panels contain unit roots. It is tested against the alternative one that assumes stationary panels. The computed z-value of the rho statistic is significant enough to reject the null hypothesis of non-stationarity in favour of the alternative one – that the panels are stationary. This is an important finding for the upcoming analysis, where the time dimension of the data will be treated accordingly.

5.4.2.3 Hausman test

According to the results of the tests mentioned in the previous sections, it is very unlikely that the dataset may be treated as a pool of individual and independent cross-sections without sacrificing unbiasedness of the coefficients. Based on the economic intuition that the impact of IT varies across industries, a natural next step would be to run fixed effects model that takes into account individual characteristics of the panels (industries). Before moving on, though, Hausman specification test will be run to check if the fixed model is indeed the right one to select.

The Hausman specification test compares the fixed versus random effects under the null hypothesis that the individual effects are uncorrelated with the other regressors in the model. If correlated, a random effect model produces biased estimators, violating one of the Gauss-Markov assumptions. Fixed effect model is preferred as a result. [Hausman (1978)]

The null hypothesis that the difference in coefficients is not systematic[8] was strongly rejected with the chi-squared test-statistic of 45,76 and

[8] That the individual effects are uncorrelated with the other regressors.

corresponding p-value of 0,0000. Based on the Hausman test, therefore, fixed effects model is preferred to the random effect model.

5.4.2.4 Fixed effects model

Based on the preceding subsection, using the fixed effects (within) estimator, time independent effects for each industry are assumed. Further on, dummy variables for the respective years 1998-2012 are introduced in accordance with the analysis of stationarity in the subsection 4.5.2.2. The results of this two-way error component model can be found in the Table 5.4 on the following page:

Table 5.4: Fixed effects regression with yearly dummies

```
Fixed-effects (within) regression               Number of obs      =       285
Group variable: Industry                        Number of groups   =        19

R-sq:  within  = 0.6509                         Obs per group: min =        15
       between = 0.0178                                        avg =      15.0
       overall = 0.0431                                        max =        15

                                                F(16,250)          =     29.14
corr(u_i, Xb)  = -0.4778                        Prob > F           =    0.0000

------------------------------------------------------------------------------
       ln_VA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ln_KL |  -.4201351   .1216053    -3.45   0.001    -.6596365   -.1806337
 ln_IttotCAP |  -.0631651   .0577344    -1.09   0.275    -.1768728    .0505426
         yr1 |  -.7409898   .0634306   -11.68   0.000    -.8659164   -.6160633
         yr2 |  -.7514082   .0635014   -11.83   0.000    -.8764742   -.6263422
         yr3 |  -.6764633   .0639275   -10.58   0.000    -.8023684   -.5505581
         yr4 |  -.6443304   .0635004   -10.15   0.000    -.7693943   -.5192665
         yr5 |  -.6137073   .0627032    -9.79   0.000    -.7372012   -.4902135
         yr6 |   -.535304   .0610575    -8.77   0.000    -.6555566   -.4150514
         yr7 |  -.4369159   .0597607    -7.31   0.000    -.5546146   -.3192173
         yr8 |   -.306797   .0587592    -5.22   0.000    -.4225232   -.1910707
         yr9 |  -.2323468   .0580427    -4.00   0.000    -.3466617   -.1180319
        yr10 |  -.1792904   .0580264    -3.09   0.002    -.2935733   -.0650075
        yr11 |  -.1347814   .0575472    -2.34   0.020    -.2481205   -.0214424
        yr12 |  -.1646665   .0573489    -2.87   0.004    -.2776151    -.051718
        yr13 |   -.121309   .0573852    -2.11   0.036    -.2343291   -.0082889
        yr14 |  -.0380963   .0568985    -0.67   0.504    -.1501579    .0739653
       _cons |   6.946692   .2406651    28.86   0.000     6.472702    7.420681
-------------+----------------------------------------------------------------
     sigma_u |  .98614096
     sigma_e |  .17519752
         rho |  .96940277   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(18, 250) =   332.32             Prob > F = 0.0000
```

Source: Stata; author's analysis

Looking at the R^2 figure, it states that this fixed effects model was able to explain 65,09 percent of variation within in the cross-sections. F-test of 332,32 is yet another proof that pooled OLS is bound to produce biased estimates. 96,9 percent of the variation is due to the differences across panels based on the intraclass correlation coefficient rho.

The coefficient for capital intensity is significant and for IT share of fixed proved insignificant, while both remained negative. According to this two-way error component model, on average, value-added goes down by 4,2 percent, if capital intensity increases by 10 percent. The same applies for a 10 percent increase in IT assets share in total assets, in which case value-added decreases by 0,6 percent.

From the economic and holistic point of view, no economy-wide trends in value-added with regard to an increasing IT share in total assets were identified. Based on the data, IT share has virtually no measurable effect on value-added on the economy level. The first hypothesis was, therefore, not confirmed, although the evidence says that it cannot be rejected either.

5.4.3 Regressions for separate industries

Panel data provided the figures relevant for testing only the first of the three hypotheses. To make research on the two remaining ones, it was necessary to leave panel data analysis framework to analyze individual panels, i.e. individual industries. This method was also used by Beede and Montes (1997) in their analysis of IT impacts on firm structure. This subsection will especially suffer from the rather short time series available – the results have to be, therefore, interpreted with caution.

Separate OLS regressions, including time trend variable for reasons specified above, were run in Stata for each of the 19 industries. The obtained results differ significantly among industries, with coefficients ranging from -0,859 for Administrative, support, waste management and remediation services (NAICS 56) to 0,550 for Arts, Entertainment, and recreation (NAICS 71). Negative coefficients were no exception – 9 regressions out of 19 in total exhibited negative elasticities of value added to IT assets' share of total assets. There are no clear patterns in the results shown in Table 5.3. A weak preliminary conclusion may be stated: capital-intensive industries tend to exhibit positive and more significant coefficients in IT share of total assets.

5.4.3.1 Durbin-Watson test

To test whether there is some autocorrelation between the error terms, which would violate one of the basic assumptions of OLS, the Durbin-Watson test was conducted for every regression and its test-statistic can be found in the table as well. In the regressions where the figure for Durbin-Watson statistic deviated from 2 significantly, a new model was set up with the assumption of serial correlation by a one period lag. The results remained almost the same even in this case.

Further regressions were run to test if the industry-specific elasticities vary over time. Information technologies at the beginning of the period of interest were far less sophisticated than it was the case towards the year 2010, changing the way IT assets influence firm’s performance within the years 1998-2012. In most cases the hypothesis that the industry-specific elasticity remained the same throughout the period could not be rejected, though.

Table 5.5: Value-added regressions by industry group (NAICS categories). 1998-2012

NAICS code	Industry	IT share of Total Assets		Capital Intensity of Production		Time Trend		Durbin-Watson test statistic	Adj. R^2	Adj. R^2 (IT variable absent)
		β	t-statistic	β	t-statistic	β	t-statistic			
11	Agriculture, forestry, fishing and hunting	-0,120	-1,170	0,032	0,040	0,059	3,330	1,731	0,875	0,871
21	Mining	0,284	0,850	1,044	1,850	0,111	8,940	2,012	0,940	0,942
22	Utilities	0,126	1,980	0,469	1,060	0,027	2,570	1,827	0,959	0,950
23	Construction**	-0,282	**-5,270**	-2,525	-16,280	0,121	18,980	2,003	0,972	0,912
31-33	Manufacturing**	0,503	**2,760**	-0,403	-2,370	0,470	4,800	1,063	0,906	0,856
42	Wholesale trade	-0,285	-0,810	0,595	1,220	0,310	4,230	1,297	0,941	0,943
44-45	Retail trade	-0,131	-0,960	0,034	0,520	0,027	0,520	0,499	0,870	0,871
48-49	Transportation and warehousing	0,157	1,590	-0,750	-3,090	0,382	14,480	1,769	0,966	0,962
51	Information	0,129	1,150	-0,118	-0,880	0,036	3,920	1,455	0,944	0,942
52	Finance and insurance	-0,009	-0,010	3,154	1,220	0,102	2,970	1,123	0,822	0,837
53	Real estate and rental and leasing	0,019	0,320	0,294	1,320	0,044	14,780	0,610	0,968	0,971
54	Professional, scientific, and technical services	0,106	0,930	-0,315	-1,860	0,059	9,090	1,554	0,972	0,972
55	Management of companies and enterprises	-0,141	-1,580	-0,651	-2,970	0,055	21,930	1,624	0,975	0,972
56	Administrative and support and waste management and remediation services	-0,859	-1,430	-0,526	-1,120	0,066	6,010	0,593	0,950	0,945
61	Educational services*	-0,073	**-2,850**	0,062	0,380	0,061	18,970	1,532	0,996	0,993
62	Health care and social assistance*	-0,491	**-3,380**	0,026	0,140	0,560	39,880	0,847	0,994	0,989
71	Arts, entertainment, and recreation	0,550	0,700	-0,984	-0,400	0,650	0,650	1,466	-0,178	-0,128
72	Accommodation and food services	0,270	1,220	0,248	0,610	0,270	0,008	1,010	0,934	0,932
81	Other services (except public administration)	0,003	0,110	0,433	2,520	0,013	3,390	2,240	0,944	0,949

Source: Stata, author's analysis

For the discussion purposes, the strength, size and sign of the relationship between IT share of total assets and industry value-added the taxonomy of the industries is reported in Table 5.4. The table was created based on the following criteria suggested already by Beede and Montes (1997):

1. Does including IT share of fixed assets variable help in obtaining a more appropriate measure of variability in value-added?

This division was made based on R^2 differences between the regression (already reported in Table 5.3) without the IT variable and the one where IT variable was included. As a rule of thumb, adding IT variable into the regression needed to add at least four percent to the R^2 measure to be regarded as a significant factor in explaining the variability in value-added. If that was not the case, it indicated a non-negligible multicollinearity between the explanatory variables, violating one of the basic assumptions of OLS, and making the obtained estimates not reliable and biased when compared to the regression, where the contribution to the model's fit is substantial. A glance at the Table 5.3 reveals that 17 industries out of 19 exhibited such phenomenon.

2. Is the elasticity of value added with regard to IT share in total assets significant or negligible?

A benchmark of coefficient 0,2 in absolute value for the IT variable was introduced for the purposes of determining the size of impact of IT variable on value-added. If the coefficient in absolute value was smaller than 0,2, the impact of IT variable was considered negligible, others were considered significant.

3. Is the estimate for the IT share in total assets negative or positive?

Finally, the basic measure for this taxonomy was the sign of the estimated coefficient. The rather contra-intuitive and at the same time not significant and reliable results with a negative sign were separated from the industries that exhibited positive signs.

Table 5.6: Elasticities of value-added, their size and relationships between IT share of total assets and value-added

Positive Relationship between IT assets' share in total assets and value-added			
Large effect, i.e. elasticity of value added > |0,2|		**Small effect, i.e. elasticity of value added < |0,2|**	
Significant contribution to R^2	Low contribution to R^2	Significant contribution to R^2	Low contribution to R^2
Manufacturing** (31-33)	Mining (21)	x	Utilities (22)
x	Arts, entertainment, and recreation (71)	x	Transportation and warehousing (48-49)
x	Accomodation and food services (72)	x	Information (51)
x	x	x	Real estate and rental leasing (53)
x	x	x	Professional, scientific, and technical services (54)
x	x	x	Other services (81)
Negative Relationship between IT assets' share in total assets and value-added			
Large effect, i.e. elasticity of value added > |0,2|		**Small effect, i.e. elasticity of value added < |0,2|**	
Significant contribution to R^2	Low contribution to R^2	Significant contribution to R^2	Low contribution to R^2
Construction** (23)	Wholesale Trade (42)	x	Agriculture, forestry, fishing and hunting (11)
x	Administrative and support and waste management and remediation services (56)	x	Retail Trade (44-45)
x	Healthcare and social assistance* (62)	x	Finance and Insurance (52)
x	x	x	Management of companies and enterprises
x	x	x	Educational services* (61)

Source: Stata, author's analysis

Divided by the first criterion, the contribution to the model's fit, only two industries were able to pass this test – Manufacturing (NAICS codes 31-33) and Construction (NAICS code 23) – suggesting that these two industries report relatively strong relationship between the value-added and IT assets in use. Not surprisingly, both of them exhibited statistically significant coefficients in IT share of total assets and capital intensity of production. Moreover, the effect on value-added is considered strong. In Manufacturing, for example, for a 10 percent increase in IT share in total assets, *ceteris paribus*, the value-added increases by 5 percent. In Construction, on the contrary, a 10 percent increase in IT variable leads to 2,8 decrease in value added.

Of the 19 industries in the dataset, 8 of them reported large effects of IT assets on value-added, whereas in 11 industries the effects were rather small. Both of the remaining two statistically significant industries - Healthcare and social assistance (NAICS code 62) and Educational services (NAICS code 61) – reported that despite exhibiting high t-statistic in IT variable, the contribution of its presence to the model's fit was very low, raising concerns that the negative coefficients are biased and not reliable.

To summarize, separate regressions were run in order to test the second hypothesis of this thesis. Based on the results and bearing in mind the limitations stemming from the rather short time period in question, it was confirmed that the impact of IT on value-added varies significantly across the industries and therefore the second hypothesis was confirmed.

6 Discussion

6.1 Issues regarding IT capital estimation

Some variation in and often controversial results of the research papers on the topic with IT assets entering the model as an independent variable, including this thesis, might be attributed to the complicated measurement of the presence of information technology in the economy. In fact, the challenge for the research is to estimate the effects of a variable that is very difficult to estimate. In order to be able to address these issues in the future, a short discussion on the measurement issues may be helpful. According to the taxonomy of Diwan and Kudyba (2003), the causes take four different forms, each of which will be discussed further below:

- low concentration of firm-level IT capital
- potential lags between IT investment and corresponding effects
- mismanagement of IT resources
- inaccurate measurement of IT capital

6.1.1 Low concentration of firm-level IT capital

IT capital represents only a small fraction of total capital employed in the economy which diminishes its potential effect on value-added. This is mainly caused by its quick depreciation in accounting figures along with the constant innovation which renders IT capital stock obsolete after a few years. Although Corrado et al. (2005) report that the annual growth rates of IT capital inputs were 18.29 percent in 1995-2000 compared to 13.62 percent in the years of 1990-1995, with Electronic Components, Computer services and Finance and insurance being the main contribution, still the relative figure of IT capital relative to total capital present in the economy has not reached two digit levels.

6.1.2 Potential lags between IT investment and corresponding effects

Many authorities in early 2000s suggested that the information technology needs time for its proliferation since it depends on the availability of its complements. The time difference between investing in IT and reaping the benefits of such investments are subject to recent research. A study conducted by Sangho and Soung (2006) suggests that the effects of IT investment in the high information-intensive industry are significantly larger than in the low information-intensive industry. Moreover, that the lagged effect is significantly larger than the immediate one, while the information intensity of the industry is irrelevant in this case. Thus, the findings imply that even the investments early in the beginning of the information era will provide their return in the end. It follows the same pattern as in the beginning of the industrial age, where the investments into steam engine were considered ineffective and too high. The economy and the business need time to learn to reap the benefits of new technology and wait for the complements to come. A steeper learning curve related to the technological change is one of the reasons for that [Lieberman(1987)].

6.1.3 Mismanagement of IT resources

The inefficient use of IT capital might be another issue. Information technology requires more skilled labour to complement it, otherwise it stays idle in the company or the capital is utilized suboptimally. Company’s management can play a key role when the efficiency of the use of IT is not optimal. This was demonstrated by Quaadgras et al. (2011) in his survey of 210 publicly traded firms, which confirmed that the more the firms are effective in making four commitment regarding IT implementation [see Quaadgras (2011)], the higher business impact from IT is realized, which in turn correlates with higher financial performance.

Another factor could be the manager’s incompetence regarding information technology and underestimation of total costs resulting from the investment in IT as the hardware and software need to be purchased, maintained and skilled labour needs to be hired and trained. According to Diwan and Kudyba (2003), this was the motivation for hiring the Chief Information Officer in the companies, whose task was to ensure into which technology to invest and, when the IT project is undertaken, to supervise its proper implementation. The implication for the software and hardware industry is the constant necessity to demonstrate value for the clients since CIOs want to spend their budgets wisely.

6.1.4 Inaccurate measurement of IT capital

The first problem faced by the statisticians when measuring the amount of IT capital in a firm is to determine market value. Due to the fast innovation trends in the IT manufacturing industry, the assets are losing its value quickly and it is very difficult to estimate it. Moreover, from the accounting point of view, the depreciation rates for IT assets tend to increase over time.

As GDP and other derived measures of output capture only quantitative changes, the potential qualitative changes resulting from utilizing IT in production are neglected. Griliches and Lichtenberg (1986) estimated the underestimation of the “quality-adjusted” growth to 43 percent in comparison with PPI index.

6.2 More thoughts on importance of IT for industries

If there was a common ground for all the models discussed in the previous chapter, it was definitely variation. The relationship between IT assets and company’s performance measured by the value-added varied from industry to industry. Now, rationale for such different impacts will be discussed in this section, mostly with the already mentioned and described economies of scale as a common denominator.

To begin with, first feature of interest will be firm size. Industries are formed from number of firms and, more importantly, these firms vary in size. An average manufacturing firm differs from an average transporting firm in number of employees, total assets at its disposal and other fundamentals. Some industries, such as mining, are dominated by a few big players, whereas in others a very large number of small firms play a key role. Moreover, an average firm in a given industry for a given year can easily represent only a small fraction of an average business in the same industry ten years later.

Table 6.1: Number of companies in different employment size classes, selected industries, 2004,2012

NAICS code	Industry	Employment size class	2004	2012	Change in %
11	**Agriculture, forestry, fishing and hunting**	**Industry total**	**25 528**	**22 046**	**-13,6**
		B group (5-9)	4 412	3 669	-16,8
		D group (20-49)	1 260	953	-24,4
		F group (100-249)	134	129	**-3,7**
		H group (500-999)	10	1	-90,0
21	**Mining, quarrying, and oil and gas**	**Industry total**	**24 157**	**29 064**	**20,3**
		B group (5-9)	3 777	4 426	17,2
		D group (20-49)	2 695	3 350	**24,3**
		F group (100-249)	499	876	**75,6**
		H group (500-999)	57	131	**129,8**
22	**Utilities**	**Industry total**	**17 675**	**17 830**	**0,9**
		B group (5-9)	2 997	2 946	-1,7
		D group (20-49)	2 470	2 746	**11,2**
		F group (100-249)	903	847	-6,2
		H group (500-999)	125	138	**10,4**
23	**Construction**	**Industry total**	**760 372**	**652 902**	**-14,1**
		B group (5-9)	126 567	101 002	**-20,2**
		D group (20-49)	46 382	35 209	-24,1
		F group (100-249)	6 016	4 444	-26,1
		H group (500-999)	360	263	-26,9
54	**Professional, scientific, and technical**	**Industry total**	**804 569**	**859 182**	**6,8**
		B group (5-9)	117 481	116 996	-0,4
		D group (20-49)	40 170	40 752	1,4
		F group (100-249)	6 352	7 020	**10,5**
		H group (500-999)	656	782	**19,2**
61	**Educational services**	**Industry total**	**78 760**	**95 872**	**21,7**
		B group (5-9)	12 583	15 354	**22,0**
		D group (20-49)	10 610	12 216	15,1
		F group (100-249)	2 391	2 982	**24,7**
		H group (500-999)	400	462	15,5
62	**Health care and social assistance**	**Industry total**	**731 917**	**883 883**	**20,8**
		B group (5-9)	172 847	193 899	12,2
		D group (20-49)	64 767	77 541	19,7
		F group (100-249)	16 601	19 783	19,2
		H group (500-999)	1 716	1 869	8,9
71	**Arts, entertainment, and recreation**	**Industry total**	**118 827**	**125 082**	**5,3**
		B group (5-9)	16 864	16 691	-1,0
		D group (20-49)	11 296	11 705	3,6
		F group (100-249)	2 256	2 690	**19,2**
		H group (500-999)	156	213	**36,5**
31-33	**Manufacturing**	**Industry total**	**339 083**	**229 221**	**-32,4**
		B group (5-9)	58 709	52 063	**-11,3**
		D group (20-49)	51 854	43 518	**-16,1**
		F group (100-249)	19 227	16 058	**-16,5**
		H group (500-999)	2 486	1 919	**-22,8**
44-45	**Retail trade**	**Industry total**	**1 119 849**	**1 063 842**	**-5,0**
		B group (5-9)	280 425	268 483	**-4,3**
		D group (20-49)	95 551	90 132	-5,7
		F group (100-249)	21 121	22 099	**4,6**
		H group (500-999)	574	277	-51,7
48-49	**Transportation and warehousing**	**Industry total**	**206 878**	**214 492**	**3,7**
		B group (5-9)	30 535	32 548	**6,6**
		D group (20-49)	20 066	20 010	-0,3
		F group (100-249)	4 601	5 012	**8,9**
		H group (500-999)	554	645	**16,4**

Source: U.S. Bureau of Census (2014), author's computations

Table 6.1 shows the comparison of the distribution of companies in the selected industries by employment size class in the years 2004 a 2012. Based on the data provided by County Business Patterns 2004 and 2012 reports [US Bureau of Census, (2014a)], 4 employment size categories were chosen for the comparison purposes: firms with 5-9 employees, 20-49 employees, middle sized firms with 100-249 employees and big corporations with 500-999 employees[9]. The total change in the number of companies for the industry was computed as a benchmark to which the employment size categories within the same industry were compared. Looking at the manufacturing industry, total number of companies has decreased by 32,4 percent but the number of the big corporations in this category (500-999 employees) decreased less. On the contrary, the firms in Mining, Quarrying, Oil and Gas industries increased their number by 20,3 percent while the category of big corporations (500-999 employees) grew by 129,8 percent of its former size. Empirical data for almost all the industries confirm the hypothesis that industry structure is in the process of constant change.

Research suggests that the impact of IT on the industry depends on the size factor of a typical firm within the economy's sector prior to an IT boom. Beede and Montes (1997) suggest that if an industry is formed from small companies with growth potential, the effects of IT proliferation will be substantial since it enables the companies to grow without sacrificing operational efficiency. In the later stage, as a medium establishment with 100-200 employees, the company will realize administrative economies of scale based on which it will gain a competitive edge over the competitors. Therefore, its value-added temporarily increases even more. Other smaller companies will cease to exist and the industry will be slowly dominated by large firms with central administration offices.

Another issue to discuss that is directly influenced by information technology is the flow of information within the companies. Small firms where the owner usually acts as a manager as well rarely have the needs and incentives to establish a managerial hierarchy for the leader to be able to avoid everyday

[9] Total numbers of companies for the industry does not coincide with the sum of the employment size categories since only some of the categories are reported in the table.

tasks and to focus on strategic planning. No managerial hierarchy means that the information flows directly to the person in charge of the discretion. As a firm grows its operations, opens a new product line, expands to another location, the ability to communicate and share information is diminished. Chandler (2003) stated that the inherent weakness in the centralized company became critical when the administrative load on the senior executives increased to such an extent, that they were unable to handle their entrepreneurial responsibilities efficiently. The organizational structure that comes to existence to solve these issues related to growth is a multidivisional firm.

Multidivisional firm consists of several divisions, all of which are in a very weak direct connection with each other. The divisions are interconnected via central offices which monitor their performance, set up remuneration schemes and work on strategic planning along with enhancing resource allocation capability and providing monitoring and controlling apparatus. Consequently, cash flow is allocated to favour high-yield uses and internal incentives towards improving the efficiency. Multinationals are often called a miniature capital market. [Williamson (1985]]. According to current research, the hypotheses of capital market efficiency as the most desirable way of capital allocation may be, therefore, in a sense, applied in the corporate world where every multidivisional firm is a small capital market of its own. These small capital markets gather an overwhelming amount of information that has to be managed via technology devices, making them a vital part of an organization.

The coordination of activities of a firm headquarters requires prompt data gathering and analysis activities. The divisional manager is responsible for transferring the information to the top management which is in charge of processing it and evaluating it, while undertaking the same process with every other division in order to be able to issue plans of actions that are in line with company's strategic goals. Top management also ensures that the goals of the divisions and ultimate strategic milestones of the company converge.

The motivation for the company management to invest in IT works as a preventive measure. On every level of company hierarchy, information may be misinterpreted – either accidentally or deliberately by a manager to pursue his own goals that do not coincide with the goals of the company. Time plays an important role as well. A lag between getting a crucial piece of information and changing the strategy accordingly caused by an employee's negligence may be potentially very costly. Similarly, a point of sale may not be maximizing its sales potential but there is no way for the top management to find out. A possible solution might be to hire a new level of managers which raises the costs significantly. Gurbaxani and Whang (1991) concluded in their work on the impact of information systems on organizations and markets that IT can solve these problems by centralizing management which leads to faster decision making processes. According to them, IT reduces external coordination costs as well, increases the degree of vertical integration and creates economies of scale in operations.

6.3 Manufacturing industry and information technology

IT enables the management of the manufacturers to monitor the company's operations closely and to exchange information with the operational divisions more efficiently. As a result of that, they are able to better optimize just-in-time delivery processes, they can produce in smaller batches that exactly match company's needs in that precise moment. There are no excessive inventories stored and financial resources can be spent alternatively. Moreover, this level of precision decreases total incurred costs and enables buying, rather than producing, the inputs needed for the final product. This is exactly the case of automotive industry. Taylor (1994) mentions that the vast majority of the car manufacturers outsource the production of the critical components to independent suppliers. Doing so, they do not operate like vertically integrated manufacturers of the industrial age. Manufacturing the components in-house simply does not pay off anymore in the new economy.

Significant and relevant results from the empirical section together with the research in this field suggest that in the manufacturing sector the IT economies of scale are present. These economies might be the source of the growing value-added in relation to the rising share of IT assets. Siegel (1997) indirectly confirms that in his study of the productivity in the manufacturing sector he found a positive correlation and even causal relationship between productivity growth and investment in computers. Even a survey in manufacturing establishments by Bureau of Labor Statistics (1994) suggested that most of the IT assets in a manufacturer’s portfolio are concentrated in production processes, mostly as sensors transmitting information about the production either to a human operator who solves the problem or to a computer that automatically adjusts the production process accordingly. This monitoring leads to better quality of the products and distinctly decrease the need for human labour. Since costs related to labour force represent a significant part of the manufacturer’s expenses, this is a factor contributing to higher value-added.

It can be stated, therefore, that recent research and the empirical results obtained in this thesis reinforce each other and a conclusion can be made. IT implementation in the manufacturing industry creates administrative economies of scale along with enhancing the production process efficiency and cutting labour costs, all of which leads to a higher value-added for a typical firm in the industry.

7 Conclusions

The foundations of the world economy that used to dominate the world were severely altered by the microprocessor invention. Although the classical economics is still applicable, the economics of information was proven to defy some of the fundamental laws. The first aim of the thesis was to elaborate on these topics of information economics, to present micro- and macroeconomic phenomena and principles as the driving forces of the information technology sector.

Since information technology significantly influences most of the industries, the second aim was to describe the modern economic environment, to introduce the challenges the companies in the New Economy face and to analyze the relationship between the cutting-edge technologies and labour force. Finally, recent empirical research on the topic of IT impact on company’s performance was presented to lay the groundwork for the upcoming analysis.

The last empirical part of the thesis provides the answers concerning the third topic of the thesis, which was to estimate the impact of information technology on company’s performance, namely on value-added. It is a function of both costs and revenues, both of which may exhibit favourable trends when IT is implemented. The empirical study was conducted on the data provided by US authorities for 19 industries of the US economy in the years of 1998-2012 with the hypothesis that there is a direct positive relationship between the IT share of assets in total fixed assets and value-added. The results did not prove that, though, and no clear patterns could be identified. Running separate regressions for the industries proved to be more meaningful for the purposes of the study, although the coefficients of IT share of capital exhibited significance only in 4 out of the 19 industries, showing the positive relationship between IT and value-added only in manufacturing industry. The reasons for this results may be attributed to the model imperfections caused by insufficient data provided by the authorities and, more fundamentally, by the issues regarding IT capital measurement.

The discussion section aimed to provide rationale for the results, especially to put the relationship between information technology and company’s performance in the context of company size and, implicitly, economies of scale. More precisely said, attempted to demonstrate that the degree of proliferation of the information technology into the sector is a function of the size of the companies in the industry prior to the IT boom.

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