ICT, Innovation and Firm Performance

An Empirical Analysis at Firm Level

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To **Viseh** and **Farhad**, my dear parents
and
Leili, my lovely sister

a unique, warm and supportive family whom I can never thank enough and will love forever

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Preface

This document is the master's thesis of Shirin Tabatabaie. It fulfills the requirements to graduate in Management of Technology (MoT) program at the Technical University of Delft (TU Delft). This program is an international program with duration of two years.

This project explores the relation between ICT, product innovation and productivity among Dutch enterprises. Through collaboration with Netherlands Central Bureau of Statistics (CBS), empirical analysis was carried out.

The content of this project was developed under the supervision of university members from the section Economics of Innovation (ECI) and from the section Technology, Strategy and Entrepreneurship (TSE) of the Technology, Policy and Management Faculty. The referee committee consists of the following members:

Professor Cees van Beers	First supervisor
Dr. Roland Ortt	Second supervisor
Msc Fardad Zand	External supervisor

Executive Summary

After computers were invented in the mid twentieth century, their applications broadened very quickly. They gradually became inevitable part of business and ICT investment became a routine for managers. In the mid 80s the impact of ICT on firm performance was questioned. A new body of literature was created in order to analyze the so called "productivity paradox". Despite the numerous contradicting results, possible explanations have been provided. The existence of paradox is not yet definite and literature has been focused on ICT value creation. With understanding how ICT creates value, many questions will be answered.

This study is a contribution to ICT value creation literature. It analyzes the mechanisms through which ICT value is created and consequently its effects on productivity. This study uses an extensive dataset, compiled as part of this project. The data set is a panel dataset including more than 50,000 Dutch firms.

In order to prevent as much mismeasuremnt as possible several issues have been considered:

- ICT usage is studied rather than ICT investment, which was previously recommended by other researchers in order to show more accurate results.
- For firm performance (namely productivity) intangible effects of ICT are also measured as well as financial measures in order to capture all enhancements.
- Panel data was compiled and used with the time range from 1996 to 2004 which is thought to be the most appropriate for ICT studies

The obtained results indicate that productivity paradox does not exist in the Dutch sector. ICT influences firm productivity through intermediate effects of collaboration and R&D, which in turn influence innovation. Innovation then enhances productivity.

I also studied the possibility of time lags between innovation and productivity. According to my empirical conclusions, I did not find certain time lag where innovation enhances productivity however I predict a time lag of four years which needs to be investigated in future (with a more extensive dataset).

Dutch firms in the dataset are divided into three sectors of manufacturing, service and others. The main differences have been between manufacturing and service sector. Service sector seems to be less innovative and less productive while using more ICT compared to the manufacturing sector. I conclude that in alignment with many other studies, service sector hasn't been efficient in using ICT.

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1 Chapter one: Research Proposal

Motivation: This chapter will give an overview of the whole paper and its structure. It is constructed in form of a research proposal which includes problem definition, motivation, scope of research, research questions, contribution and research topic relevance. Each of these topics is discussed to clarify exactly what this research covers.

Title of the research project
Information and Communication Technology, Innovation and Firm Performance
An empirical analysis at firm level

Short summary of the problem definition

Despite the common perception that ICT enhances firm performance, many researches has been done and are at the moment being carried out in order to provide scientific sound proofs about this relation. This current research focuses on the impact of ICT on firm performance, regarding an intermediate variable of innovation. Thus the main problem tackled by this research is the impact of ICT on innovation and subsequently on firm performance. More precisely the mechanisms through which various types of ICT influence innovation and consequently firm productivity are at focus.

Proposed publications

Thesis: by Shirin Tabatabaie
Subject: ICT and Innovation

Description of the research programme

Research topic and problem definition
Motivation

Computers have dramatically changed life since they were invented in the mid twentieth century. At the beginning, their applications were limited to computations and programming. Later they became inevitable part of business. Data within firms were processed by Information Systems which were in turn designed, supported and managed by Information Technology (definition from Information Technology Association of America; ITTA). In order to gain the benefits of the ICT, firms increasingly invested in the information technology.

It was not until the mid 80s when the enhancement of firm performance by ICT was questioned. Despite the increasing investment in ICT technology, firm productivity seemed to have stagnated. Computers were to be “the biggest technological revolution men have known" (Snow 1966 in Brynjolfsson 1993), but seemed to have stagnated the productivity. Robert Solow has phrased this problem as “we see computers everywhere except in the productivity statistics." This clash of expectation and statistics, as

Brynjolfsson refers to it, is the productivity paradox. Since the realization of this paradox numerous researches have been conducted investigating the relationship between ICT investment and the firm performance (productivity in particular). Many have reported this relationship strongly positive while a number of studies have shown plausible neutral or negative relation. Further studies have been done to explain these contradictions (Barua, Kriebel et al. 1995).

Although the relation between ICT and firm performance was essential to be investigated, it is a very broad issue. Study of this relation has provided an overview of whether or not ICT investments influence firm performance. Various researches have provided a more-in-depth analysis of the impact of ICT on firm performance (such as (Barua, Kriebel et al. 1995); (Melville, Kraemer et al. 2004)). However how exactly investment in ICT leads to firm performance is still in question.

The relation between innovation and firm's performance has been studied by various researchers. Many have found positive relation between these two (Crepon et al 1998; Duguet 2003; Leeuwen and Klomp 2002, Loof and Heshmati 2002, Jefferson et al 2002). Therefore innovation is seen as one of the intermediate factors that can influence productivity of a firm. However these studies have analyzed and measured the impact of innovation on firm performance rather than studying the impact of ICT on innovation. Yet what is the impact of ICT on innovation? The latter relation is of high interest to me. Not much research has been done focusing on the relationship between ICT and innovation. However positive relation has been empirically tested and shown between ICT investment and innovation and a general model explaining possible mechanisms that connect these two factors have been introduced (Delgoshaie 2007). Whether ICT enhances firm performance and through which mechanisms, is still under investigation. I intend to focus on relation between ICT and firm performance (namely productivity) through the intermediate factor of innovation. I will focus on the mechanisms through which ICT influences innovation.

Research Topic

This research is related to the productivity paradox and is intended to shed light on relevant unexplored areas in order to provide a better insight into the problem mentioned in the paradox. Therefore the main theme of the research is the impact of ICT on firm's performance. This impact is more specifically focused on innovation, through which ICT influences firm performance. Thus the research topic is mainly ICT and Innovation.

Goal of the research

The main goal of the research is to distinguish the mechanisms (how) various ICT applications used in a firm influence innovation and consequently firm performance.

Problem Definition

The main problem at focus is to find out through which mechanisms ICT influences innovation. More specifically the problem addresses the following questions:
1. Do ICT types have a positive relation with Innovation?
2. Through which mechanisms do these ICT types influence Innovation?
3. What is the impact of ICT on productivity?

Scope

As mentioned earlier, this research mainly analyses the relation between ICT and innovation. This analysis will be done at micro level (firm level). Although Macro and Meso level variables influence firm performance but analysis of these variables is out of the scope of this research. Thus the effect of Macro and Meso level factors are ignored. ICT influences many other intermediate effects besides innovation, which in turn influence firm performance. These factors are not considered in this research and neither does the relation between them. Similarly many factors influence innovation of the firm besides ICT.
Therefore the scope if the research is minimized to firm level analysis, innovation influenced by only ICT, and productivity influenced only by innovation.

Main Research Questions:

Are ICT, innovation and productivity related?

What are the mechanisms through which ICT influences innovation and consequently firm productivity?

Research Questions and Sub-Questions:

1. What is the appropriate perspective for studying the relation between ICT, innovation and productivity?
   1.1. What is ICT?
   1.2. What does innovation mean?
   1.3. What is firm performance?
   1.4. What is the correct perspective to study relation between these constructs?

2. How does ICT create value?
   2.1. What are the models provided in the literature?
   2.2. What are advantages and disadvantages of theses models?

3. What is the relation between ICT, innovation and productivity?
   3.1. Is ICT related to innovation?
   3.2. Is innovation related to productivity?

4. What is an appropriate categorization of ICT from which a better understanding of the ICT impacts can be drawn?
   4.1. Do we need a new categorization?

4.2. What is a sound categorization of all ICT types?

5. What are the mechanisms through which ICT types (of application) influence Innovation?
   5.1. What is the relation between different ICT types and innovation?
      5.1.1. What are the mechanisms involved in this relation?
   5.2. What is the relation between ICT and productivity?
      5.2.1. What are the possible mechanisms in this relation?

6. Are there time lags recognized in the relation between innovation and productivity?
   6.1. What are the explanations for the cause and duration of the time lags?

7. What is an integrative model of ICT, innovation and productivity?

8. What are the hypotheses of this research and how can they be tested?
   8.1. What is the research design to test these hypotheses?
   8.2. What are the datasets used?
   8.3. How can we operationalize the variables of the datasets?
   8.4. What are the tools and methods for the analysis?

9. What conclusions and implications can be drawn from the results of this research?
   9.1. What are the deliverables and conclusions of this research?
   9.2. What are the managerial implications of this research?
   9.3. What are the limitations of this research
   9.4. What are the recommendations for future research?

The instruments and tools to be developed or used

- A conceptual model will be developed depicting and explaining how ICT influences firm productivity: In order to show the relationship between various ICT types and firm performance, the intermediate factor of innovation will be analyzed. Further the mechanisms through which various ICT types influence innovation will be explained. Findings of the research will be depicted in a conceptual model. This model focuses on how various types of ICT impact innovation. Thus clear relations between ICT types and innovation will be provided by the model.

- Datasets from CBS will be used for conducting the data analysis. The datasets are based on questionnaires, previously formed by CBS. These datasets include CIS (community Innovation Survey), Automation Survey (ICT) and PS (productivity Statistics survey).

Contribution

This research has the following contributions to the research done in this field:
An appropriate ICT categorization will be provided. The relation between these ICT types and innovation will be analyzed. Researchers have been using ICT investment to

study the impact of ICT on firm performance. This new approach makes managerial implications more clear and precise.

A careful analysis of the mechanisms through which ICT enhances innovation will be carried out. This analysis will be of great value since it will provide the mechanism through which ICT influences innovation and thus will contribute to explain "how" various types of ICT influence innovation.

In this research a longitudinal analysis will be carried out. Carrying out a longitudinal analysis is a great advantage since it will provide us with highly reliable results. It is to be noted that availability of datasets enabling longitudinal analysis is rare. Longitudinal analysis not only provides more reliable results but it also provides the possibility to study the time lags. Thus another contribution of this research is that an analysis of time lags will be carried out. Not much attention has been paid to time lags and lack of research calls for a careful analysis.

Output

- A conceptual model at firm level, depicting the mechanisms through which ICT influences Innovation

- An empirical analysis supporting the conceptual model

- Practical and managerial implications guiding the managers to choose appropriate ICT investments in order to increase firm's innovation

Approach

The conceptual framework of the research is provided in (Figure1). After the scientific and social orientation of the problem, extensive literature study of both primary and secondary data begins. Based on the findings a conceptual model will be provided. Measurement tools for variables will be regarded in this phase. For testing the model empirical analysis will be carried out. Data from the ICT, Innovation and production statistics will be used from CBS (central bureau of statistics). Then with the aid of statistical analysis software (SPSS and Stata) econometric tests will be carried out. Besides the statistical results, practical implications will be provided. Finally a clear conclusion about the research problem and managerial implications will be given.

Scientific relevance

This research will fill in the gap that is seen in connecting ICT to innovation. Reduction of this gap will contribute to the researches that have been done about ICT impacts. This helps the better understanding of the attribution of ICT since it has been acknowledged in many studies that there is much to be done in order to understand this relation especially in the cases where negative or unexpected results appear. In addition, an empirical study will contribute greatly.

Social and Policy relevance

In practice, the outcome of this research will primarily aid managers to influence the innovation of a firm. Increase in firm's innovation may lead to better/new products (according to the definition of innovation) which in turn lead to an increase in consumer welfare.

Literature references

Primary and secondary data, including published articles and published article reviews.

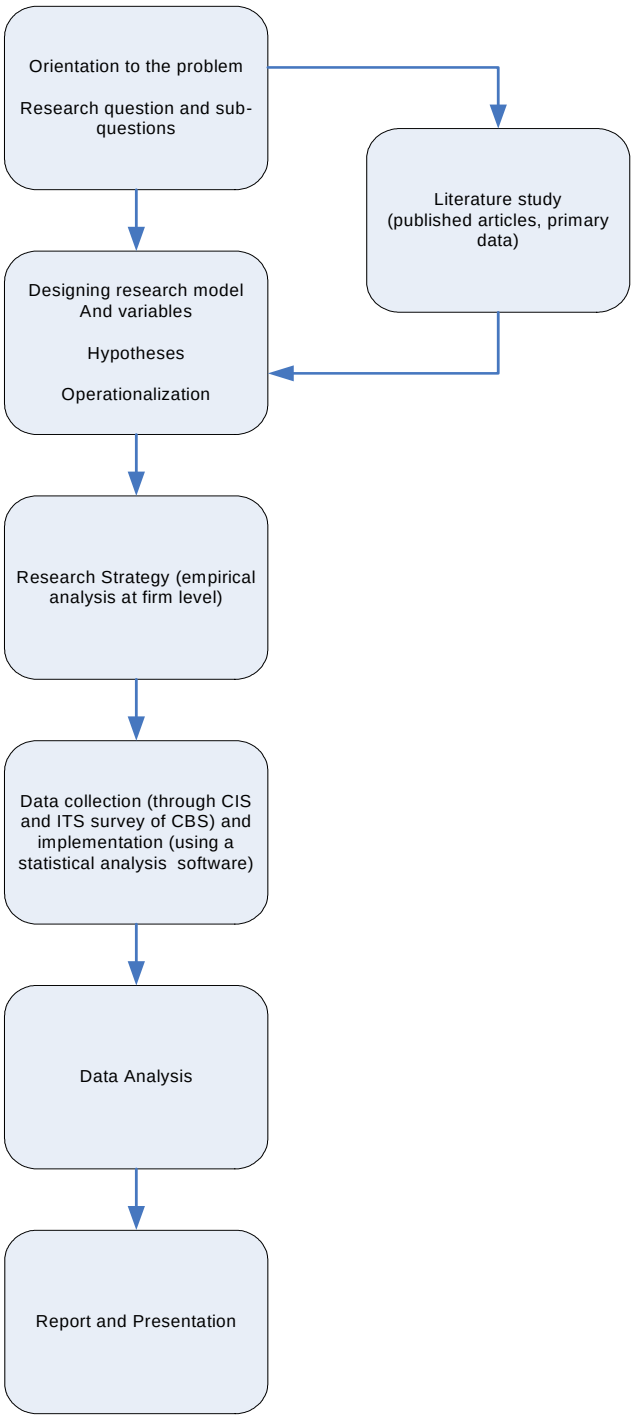


Figure1: Conceptual framework of research

Structure of the thesis

Chapter two provides definitions and the chosen perspective throughout the research. Definitions of the concepts dealt throughout the paper such as ICT, innovation and firm performance are provided for clarification and also consistency throughout the paper. The literature review is provided partially in chapter three[1] where productivity paradox and ICT value creation are explained. Productivity paradox is the origin for the motivation of this paper and ICT value creation is the main theme of this paradox which has been at focus of research in order to explain the paradox. In addition relation between ICT, innovation and productivity according to literature are provided in the rest of chapter three. At the end of this chapter the need for a new model is discussed. Consequently a new model is introduced in chapter four. Construction of the mode l is explained and relevant literature review is provided for each module used to construct the model. Based on the model and research incentives hypothesis are designed on chapter five. Before testing these hypotheses, information about data, its construction, and methodology for analysis are explained in chapter six. The results of the empirical analysis are shown in chapter seven. Chapter eight consists of the conclusion of the research and discussion. In the discussion comparison between the current research findings and the findings of other studies are provided. The final chapter (chapter nine) translates the findings of the research in practical terms for managers. Beside the managerial implications, research limitations and future recommendations are also provided in chapter nine. You can see the structure of thesis and its relevant chapter in Table 1 and relation of chapters in Figure 2.

Research Questions	Research design and methodologies	Relevant chapter
Q1	Literature review	2
Q2 Q3	Literature review	3
Q4 Q5 Q6 Q7	Literature review & Self analysis	4
Q8	Survey & Self-analysis	5
Q8	Survey & Self-analysis	6
Q8	Survey & Self-analysis	7

[1] additional literature review are provided in chapter four while explaining the construction of the new model

Q9	Self-reflection	8
Q9	Self-reflection	9

Table1 : Structure of thesis (research questions and the relevant chapters)

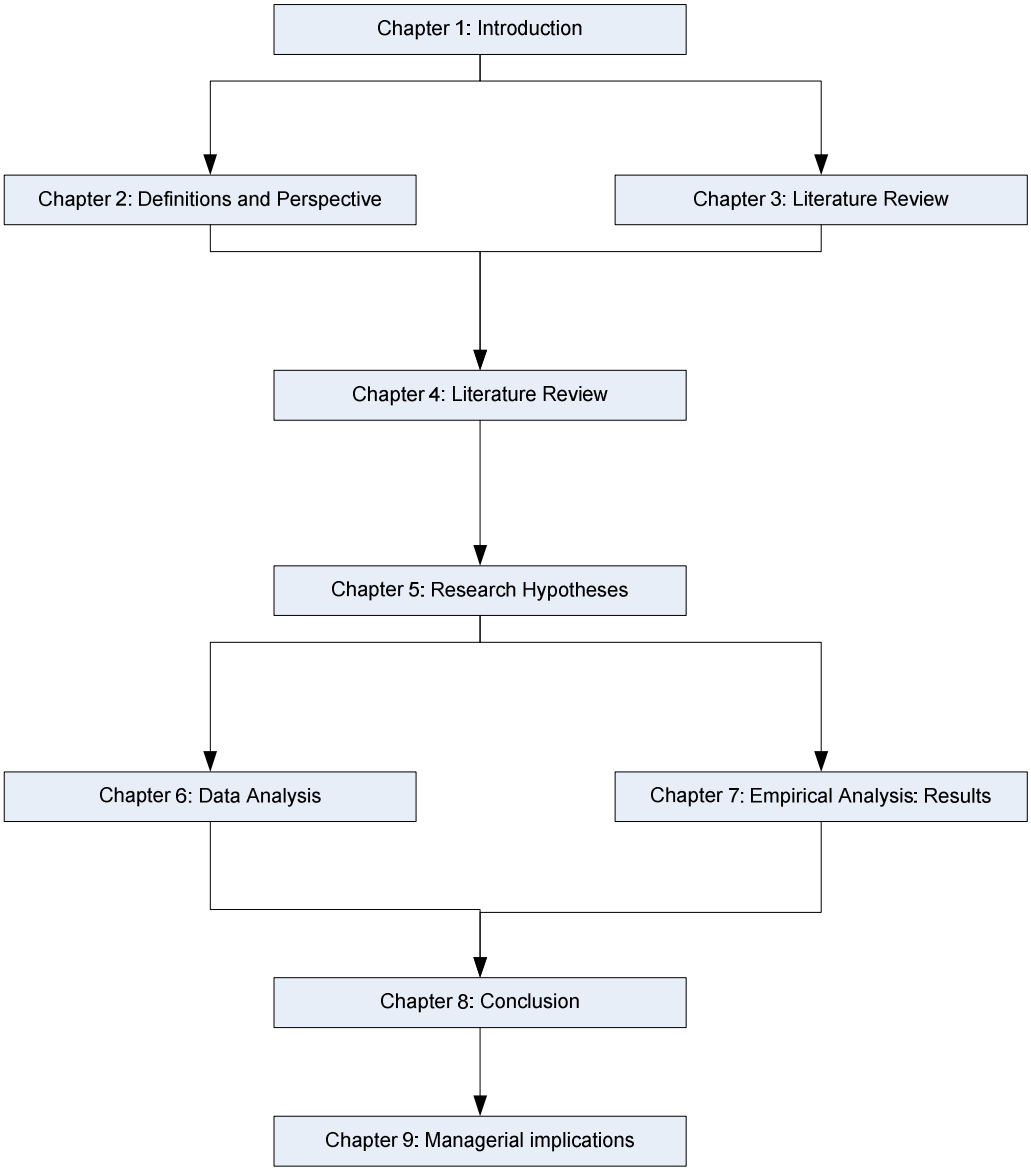


Figure 2: Structure of thesis: chapter orientation

2 Chapter two: Perspective and definitions

Motivation: In this chapter the suitable perspective for studying ICT value creation is provided after discussing the possible and common perspectives. It is important to be consistent and clear about the concepts used throughout the paper and therefore definitions of ICT and innovation are provided.

2.1 Perspectives

Study of firm has been conducted using different perspectives. Most common perspectives used by researchers are Resource based View (RBV), knowledge based view (KB) and industrial economics (IE).

Resource based theory:

This theory considers the firm as seeking to acquire hard to imitate, valuable resources and capabilities (Andreu and Ciborra 1996). It emphasizes that correct choice of combination of the resources of a firm may reposition the firm and enhances it to reach competitive advantage. To gain competitive advantage a firm needs to possess specific resources, competency and capabilities that are valuable, scarce and durable (Spender 1996). According to knowledge based theory firm is a dynamic, evolving, quasi-autonomous system of knowledge production and application (Spender 1996).
This theory is argued specifically to be useful for study of IS by Wade. They provide three important aspects of RB theory which are beneficial when studying IS:
- RB theory enhances the IS resource specification
- RB theory makes comparison among various IS resources and also between IS and none IS resources possible.
- It enhances the measurement of strategic value of IS resources

Knowledge based theory:

This perspective is common among corporate strategy theorists which see firm as a body of knowledge (Spender 1996) . This perspective is an extension of the resource based view where the resources of the firm are considered to be knowledge. It emphasizes the importance of knowledge on combining different resources of the firm. Thus in this perspective the existing knowledge is not per se important and rather the firm's ability to apply the existing knowledge to reach an optimum combination of resources is important (Alavi and Leidner 2001). Before this view was introduced, firm's primary role was considered to be knowledge creation but according to this theory the primary role of a firm is rather application of knowledge (Kogut and Zander 1992). This is where information technology can play a major role in by effectively applying existing knowledge to create knowledge and take the first steps toward forming competitive advantage (Alavi and Leidner 2001).

"Firms invest in those assets that correspond to a combination of current capabilities and expectations regarding future opportunities. Or, in other words, the knowledge of a firm can be considered as owning a portfolio of options, or platforms, on future deve1opments". (Kogut and Zander 1992)

Industrial economics or Industrial organization theory:

This theory deals with "the size structure of firms, causes of this size structure, the effects of concentration on competition, the effects of competition upon prices, investment, innovation, and so on"(Schmalensee 1988). This theory is very much focused on the functioning of markets. IO was very much based on empirical studies of different studies and gradually was strengthened theoretically (Tirole 1988).

Chosen perspective:

Spender (Spender 1996) argues that origin of tangible resources is outside the firm and the only unique resource within a firm is its knowledge which can bring competitive advantage.
KVB gives a better picture.
The primary goal of this study is to conduct an analysis at firm level and considering factors influencing internal process of the firm. Because of the underlying interest and also the scope together with the definitions of the constructs, knowledge based view is chosen.

2.2 Definitions

2.2.1 ICT

ICT stands for Information and Communication Technology. This term is commonly used nowadays and almost everyone is familiar with the broad range of its applications. However because of the variety of the applications, and for the sake of clarity we will provide a definition. In order to understand what ICT is, we first need to define a larger system; information system.

Information System (IS) is a system that collects, processes, stores, analyzes, and disseminates, information for a specific purpose (Turban, McLeanm et al. 2004). It can be simply illustrated as a system which processes the inputs and provides output. Example of inputs include data and instruction which are fed to the system and after being processed, outputs such as reports and calculations are provided (Bouwman, Hoof et al. 2005)
Information System includes hardware, software, data networks, procedures and people.

Information Technology (IT): The technological side of IS is called Information Technology. Therefore IT is only the collection of computing systems used by an

organization which includes hardware, software, databases, networks and other electronic devices(Turban, McLeanm et al. 2004). The distinction between these terms is shown in Figure3 below.

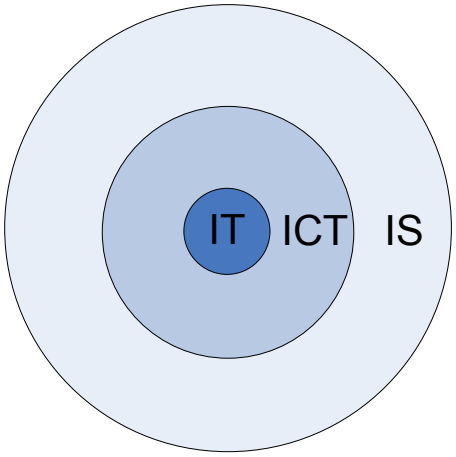


Figure3: The relationship between IS, ICT and IT.

Information and Communication Technology (ICT) is a broader term of IT which includes the communication devices enhanced by IT. In the literature the terms ICT and IT are used interchangeably and we also ignore the small difference. Thus id anywhere in the paper the term IT is used, it is assumed that it includes the communication technology as well.
IS and IT are also used interchangeably in the literature but with the provided definition above we have clarified the difference.

This paper focuses on ICT i.e. the technological enhancement that IS provides and their effects.

2.2.2 Innovation

What does the term “innovation” refer to?

Amazingly innovation has been greatly at focus for the past few decades (Fagerberg, Mowery et al. 2005). Innovation happens almost wherever people are. Therefore it is not surprising to say that it is not at all a new subject and humans have been using this concept since the beginning of mankind. “there seems to be something inherently human about the tendency to think about new and better ways of doing things and trying to put them in practice” (Fagerberg, Mowery et al. 2005).

Innovation mostly occurs in organizations where different sets of knowledge are combined. Innovation is creating new possibilities using these combinations. Therefore the two important keys seem to be accessibility to appropriate knowledge and finding the right combination of the knowledge sets (Tidd, Bessant et al. 2005). It should be noted that factors such as culture, resources, capabilities, structure, size, age and skills

influence innovation as well. However in this paper the main focus is on the knowledge sets and its management (since the specific impact of ICT is at issue).

Since innovation is mainly about the knowledge component, managing knowledge becomes highly important for successful innovation. Information and Communication Technology (ICT) can play a vital role in enhancing innovation in a firm.

Different types of innovation have been discussed by different authors. Most common classification of innovation in a firm is product, process and organizational innovation. Product innovation evokes a less abstract notion than the other two. Process and organizational innovation are more complicated and may take quite a while to occur (especially organizational innovation). Consequently many factors involve influence them. It is very difficult to focus on all three innovation types in this paper and it is rather not possible to capture al influential factors which have impact on them. Also in general process innovation and rather organizational innovation are very difficult to measure. This paper has thus been narrowed down to product innovation i.e. new product development. I have to note that product innovation is not completely separate from process and organization. Innovations occurring in organization and also its process may lead to new or improved products and vice versa. I will explain the intertwined relationship of product innovation with process innovation and organizational innovation separately.

Organizational innovation' is the creation or adoption of an idea or behavior new to the organization (Daft 1978; Damanpour and Evan 1984; Damanpour 1996 in (Lam 2004)). The new idea created or adopted by the firm (that has gone through organizational innovation) leads to a new product. Therefore the new product is the outcome of the organizational innovation. Many researchers have focused on how certain organizational structures facilitate the creation of new products, especially in relation to fast changing environments.
On the other hand rapid change in product innovation requires changes in organization. Organization may need to change its structure, behavior and underlying processes.

Process innovation is closely related to product innovation as well. Process innovation has sometimes been referred to as an alternative to product innovation, especially if it facilitates production so that the product could be produced at lower cost. Innovations in process facilitate the production of new products through increase in flexibility or range of adaptation(White, Braczyk et al. 1988). On the other hand production of a new product may require changes in the existing processes. For example new machine acquirement supports the production of a new product.

2.2.3 Firm Performance

Firm performance is a concept explaining the success of a firm. It basically describes how a firm has performed over a period of time. There has been a great effort in finding measures for this concept because it explains a rather important notion. By finding a measure for firm performance a firm can compare its performance across different periods of times and consequently performance of different firms can also be compared

to each other. However no unique measure has the ability to capture all aspects of performance(Snow and Hrebiniak 1980).

Among the different measures of firm performance a general category of financial and non financial can be drawn. Financial measures rely on economic aspect of efficiency. They explain how efficient firm has performed. Efficiency has been recognized a one of firm's objectives. Firms thrive to achieve efficiency, which is closely related to cost reduction.

Efficiency is not the only objective firms thrive for. So not only the efficiency is important but also the emphasis on effectiveness has increased. Firms in the third millennium are called effectiveness-seeking enterprises rather than efficiency-seeking enterprises (Hunt and Duhan 2001). While the emphasis of efficiency-seeking enterprises is on cost, effective-seeking enterprises focus on increasing customer value. In other words, they focus on producing more reliable products and higher quality (Hunt and Duhan 2001). Therefore non-financial measures would be more appropriate in measuring firm performance with regard to effectiveness.

In this paper I will use measures for each of these objectives; Productivity is used for efficiency objective while intangible effects are used for measuring effectiveness.

Productivity is one of the common measures used to measure efficiency. Productivity is measured as the output divided by input. Efficiency occurs when less amount of input (time, cost) are used to produce the output. Productivity has been recognized as a reliable measure. Although productivity isn't everything, in the long run it is almost everything (Brynjolfsson and Hitt 1998).

As mentioned earlier, effectiveness is also important in measuring firm performance. Effectiveness relies on better quality and higher value for customers. Based on this definition relevant measures for effectiveness are derived in chapter 6.

3 Chapter three: Literature Review

Motivation: The literature review is partially captured in this chapter. The rest of the literature study is covered in chapter four while introducing the new model (the reason is that some concepts were closely related to the way model is constructed and providing the relevant literature review in a separate chapter was not logical). Productivity paradox will be discusses. Evolution of research done since the emergence of this paradox will be provided. Most important models found in literature that addresses the productivity paradox solution (more specifically: ICT value creation) will be provided. Literature review about the ICT and innovation and about ICT benefits in firm will be provided. This will take us a step closer to introducing a new model. Therefore the last section of this chapter is dedicated to a discussion about why a new model is needed.

3.1 Productivity Paradox

Since late 1980s a paradox emerged which became one of the central themes regarding ICT research. In 1987 Robert Solow presented this paradox with a question:

"You can see the computer age everywhere but in the productivity statistics." (Solow July12th 1987)

Despite huge ICT investments the productivity of firms was not showing improvement. Productivity is one the basic and economic measure of firm performance. Therefore this paradox revealed that investments in ICT don't pay off and don't improve firm's performance. In order to gain better understanding of the paradox and investigating the cause for it a new wave of research began. The central theme to these studies was whether ICT investment improves firm productivity or not.

The results of studies were very different. Some acknowledged the paradox and others completely disagreed with its existence. As I will discuss later, there were main reasons why the results were not consistent. The two tables below show different studies and the result. Tables are constructed using information in Brynjolfsson (1993) and Barua et al (1995). Table 1 shows the studies concluding positive correlation while Table 2 focuses on studies that conclude negative correlations.

Researcher	Positive correlation between ICT investment and productivity
Morrison and Bendi (1990)	Marginal benefits of ICT investment is low
Weil (1990)	Contextual factors make a difference
Barua et al (1991)	ICT improves intermediate output
Siegel and Griliches (1991)	Positive result using industries
Brynjolfsson and Hitt	Positive result on return on investment for ICT
Cron and Sobol	Positive and negative results
Harris and Katz	Positive but weak

Table 1: studies that conclude positive contribution of ICT to productivity

Researcher	Negative correlation between ICT investment and productivity
Loveman (1998)	ICT investment does not increase productivity
Strassman (1991)	ICT investment does not increase productivity
Roach (1991)	ICT investment does not increase productivity
Pearson (1990)	ICT investment does not increase productivity
Bailey and Chakrabarti (1988)	ICT investment does not increase productivity

Table 2: studies that conclude negative contribution of ICT to productivity

As mentioned before there have been numerous studies in this field. Some have focused on the correlation between ICT investment and productivity. These studies focus on whether this correlation is positive or negative. Others have focused on the cause of this correlation. These studies have gained more interest and consequently studies providing new perspective for this paradox have gained more importance.

Among the reasons for the existence of this paradox are the following.

Brynjolfsson (Brynjolfsson 1993) has mentioned the following to be the main reasons:

1. mismeasurement of outputs and inputs
2. lags due to learning and adjustment
3. redistribution and dissipation of profits
4. mismanagement of Information Technology

Weil (1990) focused on ICT use and concluded that productivity enhancement depends on the contextual variables. In other words depending on the ICT application, the performance produced differs. More specifically he found that transactional ICT applications such a s data processing contribute to productivity enhancement while strategic systems such as sales support do not contribute to productivity at all (Brynjolfsson 1993).

Brooke (1991) argues that the initial impact and goal of ICT is to increase product variety. As a result an economy of scale and thus profitability decreases.

Before the 1990s studies were focused on the country level and gradually moved toward industry level. It was after 1990 when more data became available of firm level and thus research was guided toward firm level analysis. Firm level of analysis is very advantageous because many other possible interactions between ICT investments and ICT value creation would then be possible. Also mediating and moderation variable effects could be included in the analysis. Thus at firm level these included variables such as firm size, ICT personnel, firm innovation capabilities, among many other

characteristics of the firm, of its external environment and of the ICT investment management. Thus firm level of analysis provides can provide a more accurate analysis.

When research began on firm level of analysis in order to explain the paradox careful analysis of ICT value creation was studied.

There have not been many studies providing an integrative approach for explanation of value creation process. Barua et al (Barua, Kriebel et al. 1995) introduce the following model which is a two stage model. In this model ICT value is create in two stages. In the first stage industry variables and in the second stage economy wide variables impact the value creation process. Barua argues that as ICT value is created it has its intermediate impact and possibly final impact. The model is shown in Figure 4 below. Intermediate outputs discussed were capacity utilization, inventory turnover, relative inferior quality, relative price and new products.

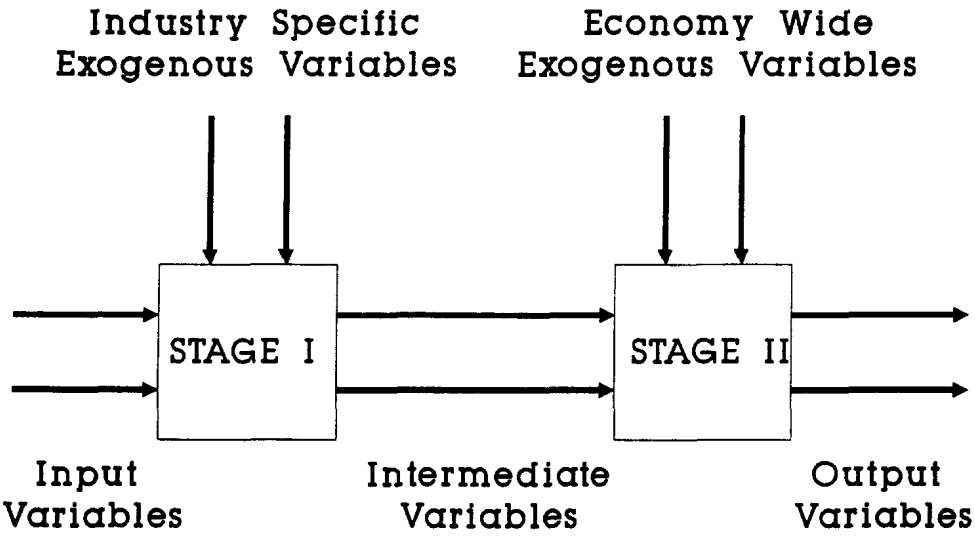


Figure4: Barua et al. (1995) ICT value creation model

Barua's model however lacks firm-specific variables. In addition is extremely general and simplified. In other words the input, intermediate and also output variables are not clear cut constructs. This model is beneficial in the sense that it gives a general overview of the value creation process but is not at all sufficient and complete to be used in different contexts.

Melville (Melville, Kraemer et al. 2004) introduced a more detailed model which unlike Barua it also deals with internal firm factors such as partners, resources and business processes. This model explains that ICT together with complementary resources affect business processes which in turn influence business performance and this then leads to organizational performance. This model can be seen in Figure 5 below.

Although compared to Barua this model has extensively improved ICT still lacks mechanisms explaining how ICT impacts business processes. What I mean is that the link between ICT resources and business process is very ambiguous and not applicable in specific firm context. Although we are now much clearer about the value creation process of ICT, more detailed explanations on "how" each construct linked to the next is missing.

The new model proposed in chapter three is aimed at contributing to this lack in literature. Before introduce the model several relations within a firm will be discussed.

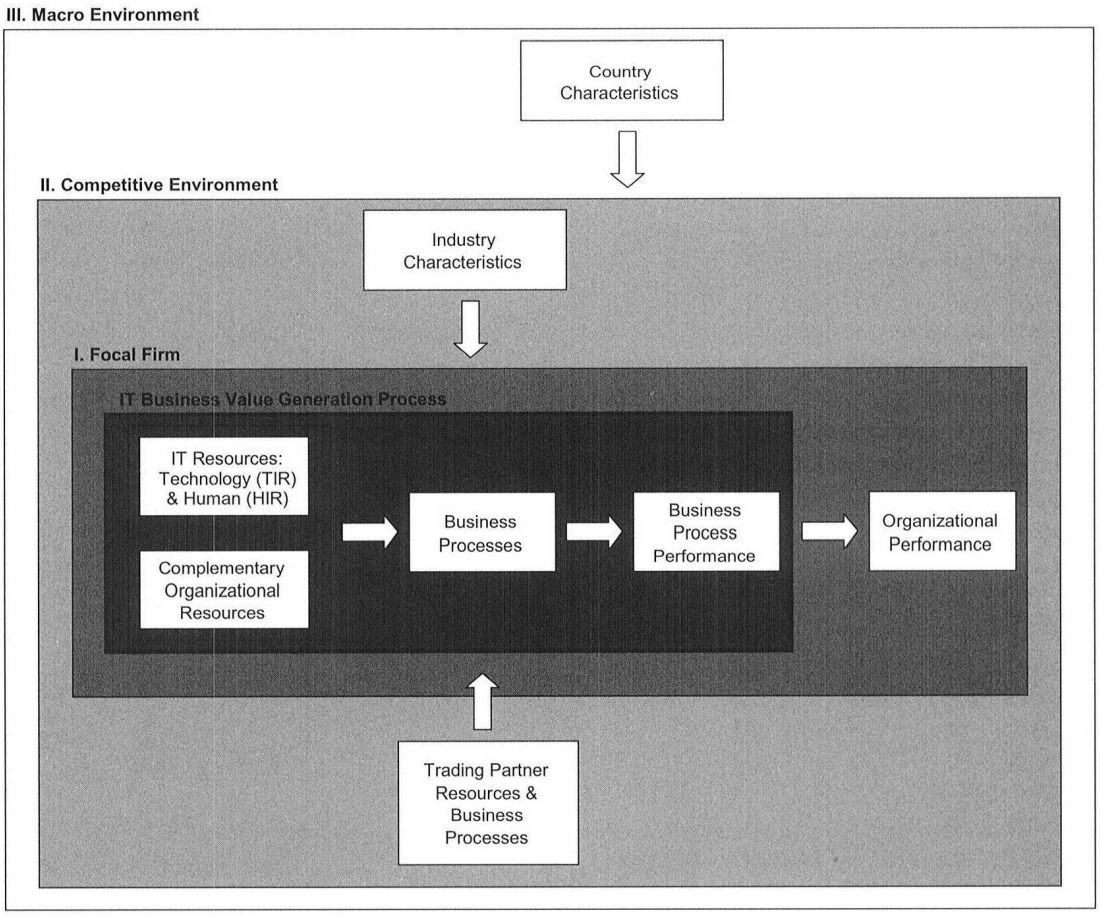


Figure 5: Melville (2004) ICT value creation model

To conclude we can mention the following remarks:

1. The paradox does not really exist anymore. However literature lacks an integrated and sufficiently detailed model for explanation. Further research should be centered around ICT value creation

2. in order to deepen our understanding about ICT value creation closer investigation of how (through which mechanisms) ICT value is created is necessary
3. Small number of studies use and have access to large datasets. Empirical studies on large datasets will reduce many obstacles especially the time period covered is large.

3.2 ICT, Product Innovation and Productivity

As we have mentioned in the previous section, productivity paradox has been more or less faded away and focus has been shifted to the strength and influencing factor for ICT and productivity, rather than existence of the relation. In order to explain this relation better, new factor should be introduced between ICT and productivity. One influential factor is innovation. Innovation has gained importance in the past few decades. Before that innovation was limited to product innovation and did not even imply all sectors. Now innovation is not limited to a product or a few industry sectors. Product innovation is one of the many types of innovation. It is very common to regard service as product. So product innovation is also applied to service sector. Beside product innovation, process and organizational innovations exist. This is a common classification for innovation. We will now analyze the relation between ICT and Product innovation.

3.2.1 ICT and Product Innovation

But does ICT relate to innovation at all?
Product innovation is either about creating a new product or improving the quality. Improves product quality (Tarafdar and Gordon 2007) and thus enhances innovation. In addition, one of ICT outcomes is considered to be innovation (Bouwman, Hoof et al. 2005; Tarafdar and Gordon 2007).

ICT increases the speed and responsiveness of the firm(Brynjolfsson 1993) which in turn enhance successful innovations.

Yang (Yang, Lee et al. 2007) has conducted a study in which ICT application have been related to different innovation types previously provided by Swanson (Swanson 1994). The innovation categories are:

Type I innovation: IS process innovation
Type II innovation: Product and business administrative process innovation
Type III innovation: Inter organizational IS innovation

Table below shows the relevant ICT application attributed to each other above innovation categories.

Innovation type	ICT	Researchers
Type Ia innovation	Outsourcing	Loh and Venkatraman (1992) and Grover *et al.* (1997)
	IS services	Lind and Zmud (1991)
	Work station	Moore and Benbasat (1991)
Type Ib innovation	CASE Tool	Orlikowski (1993) and Grover *et al.* (1997)
	DBMS and DDBMS	Nilakanta and Scamell (1990) and Grover *et al.* (1997)
	Data administration	Swanson (1994)
	OOPS	Grover *et al.* (1997)
	Spreadsheet	Brancheau and Wetherbe (1990)
	4GLs	Fichman and Kemerer (1993)
	EDP	Moch and Morse (1977)
	Modern software practices	Zmud (1984)
	Software engineering technology	Fichman and Kemerer (1993)
Type II innovation	Expert systems	Grover *et al.* (1997)
	E-mail	Grover *et al.* (1997)
	EIS	Grover *et al.* (1997)
	Teleconferencing	Grover *et al.* (1997)
	Information center	Swanson (1994)
	ATM	Johannes and Harianto (1992)
	GDSS	George *et al.* (1992)
	End-user computing	Moore and Benbasat (1991) and Wildemuth (1992)
	Business computing	Attewell (1992) and Garcia-Morales *et al.* (2006)
	General purpose individual computing	Burkhardt and Brass (1990)
	Telecommunication tech	Grover and Gosler (1993)
Type IIIa innovation	MRP	Swanson (1994)
	CAD/CAM	Grover *et al.* (1997)
Type IIIb innovation	Open system	Chau and Tam (1997) and Huang and Lin (2006)
	On-line trade	Chen *et al.* (2002)
Type IIIc innovation	EDI	Grover *et al.* (1997) and González-Alvarez and Nieto-Antolín (2005)
	ISDN	Lai and Guynes (1994)
	BITNET	Gurbaxani (1990)

Table I.
ICT type and relevant studies

Table 3: ICT applications and their relevant innovation categories (Yang, 2007)

The literature on IT and the relationship with successful innovations and performance is to a great extent based on case studies and conceptual frameworks (Powell and Dent-Micallef, 1997, p. 375 in (Johannessen, Olaisen et al. 1999).

Recent studies in the ICT field emphasize that an important task of ICT is to create business value through the development of new products and services(Barczak, Sultan et al. 2007). ICT is also considered to be a source for different capabilities such as innovation capability which mat result in potential competitive advantages for a firm (Barczak, Sultan et al. 2007).

ICT is considered to improve innovation in many aspects. Johannessen (1999) believes that ICT applications increase effectiveness and the successful implementation of

innovations. He argues that automation if tasks through ICT plays an important role in the successful implementation of innovation.
According to the definition of innovation provided earlier, innovation happens when several sets of knowledge are combined together in a new way. On the other hand ICT applications deal with knowledge and combining knowledge. Many studies acknowledge its support for knowledge combination. Johannessen (1999) argues that ICT facilitates coordination & coordination of activities through Integration of Knowledge. ICT technologies can also enhance learning capabilities, through facilitating the reuse of existing knowledge and providing additional communication channels to stimulate company-wide communication and recombination of internal and external knowledge (Corso, Martini et al. 2003).

The direct relationship of ICT and product innovation is also apparent in literature. Corso (2003) states that ICT can significantly enhance a firm's information processing capacity, which can improving the abilities of managing and integrating all activities which contribute to the overall process of product innovation into a value chain.

In a study by Gordon and Tarafdar (Tarafdar and Gordon 2007) provides and integrated view on how ICT enhances innovation. They introduce five IT competencies and explain how they enhance innovation. See Table 4.

Related ICT resources	ICT competency	Enhancing innovation
- hardware, for storing knowledge and processing information requests - software, such as organizational portals (Benbya et al., 2004; van Baalen et al., 2005) and knowledge sharing software (e.g. Notes), - robust data communications infrastructure	information and knowledge management	- Innovation process is knowledge intensive, - KM helps users find K, integrate knowledge and mine tacit knowledge (Hackbarth, 1998), - KM influences innovation though development of knowledge worker - KM encourages reuse of knowledge (negative)
- hardware for storing and manipulating product and process data, - software for project planning and tracking (e.g. Microsoft Project), software for group coordination, and - a robust data communications infrastructure.	project management	- manage portfolio of innovations, - PM keeps teams members focused, - PM helps leaders operate efficiently)
- Collaboration and communication are	Collaboration and communication.	Initiation stage - one person's creativity can be

organizational and ICT competences. They draw or hardware and software infrastructure such as e-mail, groupware, portals, shared storage, and remote conferencing.		stimulated by another person presenting new knowledge or information that triggers an innovative idea or solution (Madjar, 2005). development and implementation stages team might include members with specific knowledge and competences from around the world, including possibly suppliers, vendors, and others outside the firm (McKnight and Bontis, 2002; Zakaria et al., 2004).
	Business involvement.	- Innovations often result from incorporating information technology into a product, service, or process. Thus leaders must - understand the possibilities for assimilating ICT into their companies' offerings or - understand their companies' business sufficiently well to propose ideas that are consistent with their business strategies. - Many innovations have been attributed to this type of cross-knowledge, which we call "business involvement" (see, for example, Abetti, 1994; Dvorak et al., 1994; and McKenney et al., 1997).

Table 4: ICT resources, competencies and their relation to innovation enhancement (Tarafdar & Gordon, 2007)

Not all studies show a positive relation between ICT and innovation. ICT is also known to stifle creativity and innovation by standardizing, automating, and institutionalizing existing processes and workflow (Tarafdar and Gordon 2007).

The critical innovation factors linked to ICT were introduced by Johannessen (Johannessen 1994). They include:

1. the role of the change agent: A change agent is someone who does everything to "sell" the innovation to others in the organization. Tools used by a change agent is Communication through workstations associated with internal networks

2. organizational culture: ICT that enhances integration focuses on integrative aspect of culture and consequently enhances innovation process management style: Successful innovations are associated with an open management style. Communication-related IT enhances this open management style. In addition ICT integrates learning about complex group interactions, provides mental model, enhances learning through games and interactive activities and provides dynamic modeling tools.

3. the market: being updated and well informed about environment (market) is vital for a firm. ICT tools make customer use of databases possible, ease access to information and provide what is referred to as customer induced innovation.

4. co-ordination and service: communication related IT enhances the coordination and service quality for customers.

Therefore according to literature ICT is related to product innovation and can influence it. But as we saw before, there is no complete and integrated model capturing all ICT impacts. Many regard ICT as one entity and many simplify ICT value creation process. Next section clarifies the need of a new model.

3.3 Why a new model?

As mentioned before there are not many models using an integrative approach to study ICT value creation. We discussed Barua and Melville's models.

We saw that Barua's model lack firm-specific variables and are extremely simplified. This model is beneficial in the sense that it gives a general overview of the value creation process but is not at all sufficient and complete to be used in different contexts.

Melville's model is much more detailed and gives a better overview of ICT value creation process but it still lacks mechanisms explaining how ICT impacts business processes.

So more detailed explanations on "how" ICT value is created is still missing.

As mentioned before, the primary goal of this research is to study how ICT influences innovation and productivity and introducing mechanisms through which ICT influences

innovation and productivity is at focus. With the literature review innovation is the chosen factor in between the ICT relation to productivity.

By conducting an extensive literature review I conclude that there is no integrative model including analyzing the relationship between ICT, innovation and productivity simultaneously. There are many studies linking two of these subjects together. Despite mentioning the interrelation between each pair, research in this field really lacks an integrative model providing the general overview of the relationship between these three constructs.

In the previous models which showed the relationship between two of the above mentioned constructs, very general approaches had been taken. Usually the correlation (positive and/or negative) correlation between either pair had been the focus. Generally previous they suffer from oversimplification. Intermediate effects have been completely ignored. Thus less attention has been paid to "how" part of every correlation. Mechanisms through which for example ICT is related to productivity have not been carefully investigated.

Many studies are sector-specific which is due to data limitations.

Regarding ICT with innovation and ICT with productivity, mainly ICT investment had been taken into consideration. ICT usage which is suggested to be more important than investment has been ignored. Johannessen (1 999) found that focusing on the use of IT might be a promising route for studying the relationship between IT and successful innovations, and between IT and performance. In this regard I will be using "ICT usage" rather than "ICT investment".

Similarly productivity has been treated more in financial figures although the intangible outcomes of ICT and innovation have been stated many times by different authors (Brynjolfsson. and Hitt 2003 a). This is of course because measuring these intangible outcomes is difficult and financial statistics seem to be more accurate since they more or less capture major part of the outcome.

4 Chapter four: Conceptual model

Chapter four introduces the new model which is based on the literature study (partially available in chapter three and partially available in this chapter). Primarily the advantages of the new model are discussed. For the new model a new classification of ICT is introduced after analyzing the classifications previously introduced by other researchers. Each component of the model will be discussed as well as its relationship with other components. At the end of this chapter, the issue of time lags is discussed.

4.1 Advantages of the new model

The model I will be introducing has the following advantages:

- Capture the three notion of ICT, Innovation and firm productivity simultaneously. This gives the opportunity to have a better and a different overview for a firm.

- Although the model provided you with general picture of how the three notions are related to each other, it also presents the mechanisms or the intermediate effects through which ICT and innovation link together. Innovation itself is also seen as a mechanism in this model. This will help us to better understand "how" these notions are linked to each other.

- In this model ICT usage is at focus rather than ICT investment. This will give a new perspective on the effect of ICT usage on Innovation and productivity.

- In this model output also included intangible effects. Thus this model provides and proves the impact of ICT from intangible aspects.

- This model is not sector-specific and can be applied to different sectors of industry.

- Several links of the model will be supported quantitatively. As mentioned before (chapter2) the number of quantitative research in this field is limited. Quantitative research based on panel data (which can provide more accurate results) is limited to a small number of studies.

4.2 ICT categories

ICT has been classified in different papers. ICT applications cover a broad range of activities and functions in an organization. One contribution of this research is to find a suitable classification of ICT applications, so that it will help us understand ICT value creation process better. There are several common classifications of these

applications which have been used. I will discuss each and then introduce an appropriate categorization. Before I introduce these common classifications I will provide a concise analysis of how firms benefit from ICT. This will give a general overview about the extent of ICT impact in firm and will help us understand the classifications better.

4.2.1 ICT Benefits:

ICT applications consist of a broad range of application.

- With regard to innovation intensive projects ICT offers applications supporting workflow automation and group collaboration Bardhan (Bardhan, Krishnan et al. 2007).

- By automation ICT improves workflow Buhler and Vidal, 2005 in (Tarafdar and Gordon 2007)

- It also enhances company's flexibility to respond to customer needs (Tarafdar and Gordon 2007) and Brynjolfsson (1993)

- improve communication between a company and its customers and suppliers (Tarafdar and Gordon 2007)

- Innovative (improving innovators' ability to collaborate with one another and search for relevant information and knowledge) (Tarafdar and Gordon 2007)

- speed enhances successful innovations Kessler and Chakrabarti (1996).

- increase effectiveness and the successful implementation of innovations (Johannessen, Olaisen et al. 1999)

- more available and more quickly retrieved information. Huber (1990 in Johannessen 1994)

- knowledge integration within companies as important for creating sustainable competitive advantages. Grant (1996a; 1996b)

- Facilitates coordination & coordination of activities through: Integration of knowledge, internal communication,

- Automation of tasks (initial design of processes) + enhancing successful implementation of innovation (Johannessen, Olaisen et al. 1999)

- workflow automation(Barczak, Sultan et al. 2007)

- facilitating group collaboration. (Barczak, Sultan et al. 2007)

- enhance learning capabilities, through facilitating the reuse of existing knowledge and providing additional communication channels Corso (2003)

- enhance a firm's information processing capacity, thus improving the abilities of managing and integrating all activities Corso (2003)

Barczak et al (2007) has reduced this list which is further reduced by Johannessen. Johannes believes that ICT have three major effects which are: efficiency, effectiveness and flexibility.

ICT effect	References
o Cost savings o Employees productivity o Employees motivation o Production capacity o Increasing income revenue o Higher variety of services o Presence in other regions o Higher degree of internationalization o Acceleration of employment generation o Skilled labor use o Flexibility to customer demands o Delivery speed o Temporal availability o User friendliness o Reliability Regulations, standards	(Barczak, Sultan et al. 2007)
o automation effects (efficiency) o informational effects(effectiveness) o transformational effects(flexibility)	(Johannessen, Olaisen et al. 1999)

Table 5: ICT effects across firm

In short, ICT effects across firm are diverse and several attempts have been taken to classify them as you saw above. To generalize all ICT impacts Will classify them according to their roles.

4.2.2 ICT classifications according to literature:

The following classifications have been provided by other researchers:

- One simple classification of ICT is based on its application: internal or external. ICT is used internally and externally in an organization. It's used internally across all functions of the organization such as manufacturing, accounting, finance, marketing, HR. Some applications are being used cross functionally such as Transaction Process System (TPS). TPS crunched numbers, summarizes, organizes transactions and data in accounting and assures the accuracy of transactions across the organization. Applications such as Enterprise Information System (EIS) and Enterprise Resource Planning (ERP) are also carried out across the enterprise. Beside these internally applicable ICT applications, many applications are used externally, some to improve communication (EDI) and some to improve collaboration (Customer Relation Management)(Turban, McLeanm et al. 2004).

- Another classification of ICT is based on supply chain. There are some ICT applications supporting each section of the supply chain (Turban, McLeanm et al. 2004):
    - Internal (TPS, corporate wide IS, functional IS)
    - Upstream (e procurement)
    - Downstream(IT support in downstream is from two aspects: 1. IT supports customer relationship, 2. It supports order taking and shipment)

- A similar classification has been provided for IT applications in project management (Bardhan, Krishnan et al. 2007). IT applications have been distinguished from each other through the following classification:

    - basic communication technologies (BCT)- IT used for simple tasks
    - enterprise software technologies (EST)- IT applications used for well-structured projects that are characterized by formal guidelines and standard operating procedures
    - groupware and collaboration technologies (GCT)- For unstructured and volatile project work, more flexible (e.g. planning and architecture) Enabling rich, free-form communication, they help participants to communicate their changes, synchronize with each other's work, and adapt to changing organizational conditions

- McAfee (McAfee 2006) provides another classification:
    - Function IT: IT that assists with the execution of discrete tasks (e.g. CAD, spreadsheets)
    - Network IT: IT that facilitates interaction without specifying their parameters (e.g. email, wikis)
    - Enterprise IT:P IT that specifies business processes (e.g. ERP, CRM)

- Mooney (Mooney, Gurbaxani et al. 1996) has also provided a classification for IT. He has focused on the impact of ICT on operational processes and management processes. The first are improved by improving the efficiency through automation and the latter processes are improved by enhancing the information exchange channels. The enhancing dimensions of IT on business processes are:
    - Automational: application that are implemented as substitution of labor
    - Informational: applications which deal with information

- Transformational: applications supporting process innovation and transformation

The above mentioned classifications have several shortcomings. They are either very general (like internal and external) or not applicable to use for innovation context. For example the internal, external classification is very broad. This prevents us from having a deep understanding and practical overview about different types of ICT applications used in a firm. Other classifications are more detailed, but they are either specific for a certain field (e.g. Bardan and Krishnan's classification is specific to projects or project level innovation) or they are not applicable for innovation context (e.g. Turban's classification based on supply chain is not helpful to be related to innovation). MacAfee and Mooney's seem the most appropriate. MacAfee's classification is task oriented. In order to understand the impact of ICT with innovation and productivity a deeper understanding of IT impacts is needed. For example primary effect (role) of ICT would clarify what IT does than understanding what tasks each application is capable of doing. Mooney has focused on impact of IT (their roles). One shortcoming about Mooney's classification is its incompleteness. I intend to introduce a new classification which is an extension of the combination of these two models.

The new classification enables a better understanding of the level ICT is used and it's linkage to the level where its impacts occur. Moreover the proposed model adds to the literature on ICT value and provided a better understanding of how this value is created. The first step for the model construction is categorization of ICT applications.

4.2.3 New ICT classification

ICT is broadly used across the firm. Not only each department separately benefits from Information Technology, but also the organization as a whole applies specific ICT applications which are used across separate departments.

These ICT applications cover many different functions and each play a different role in the organization. With this variety in number and also variety in their effect of ICT applications, there is a need for a sound classification. In this section ICT applications will be classified regarding the knowledge perspective as well as their consequences and effects on innovation (new product development).

The new ICT classification divides ICT into three different categories:

Category One: ICT applications providing knowledge in reach
Category Two: ICT applications providing enriched knowledge
Category Three: ICT applications integrating knowledge

Category one includes ICT applications with the primary goal of increasing extent of access for individuals or firms. For example internet has enabled firm's global access.

Therefore if a firm uses internet, it has increased its access to information. Therefore use of internet has broadened firm's access to information.
Category two includes applications which process information and provide rich knowledge. This might be a first level or second level processing. Firs level processing includes simple activities such as storage, simple operations, information retrieval, etc. An example of ICT application for first level processing is a backup system. Firms retrieve information using a backup system. An example of Second level process is a decision support system (DSS) which is an interactive software-based system intended to help decision makers compile useful information.
The last category included applications which combine and integrate knowledge from different sources within a firm or across firms. A common example is Enterprise Resource Planning (ERP) which is a cross-functional and enterprise wide business support system.

As mentioned before the classification is based on ICT roles and what they actually do in a firm. To better understand the above classification, ICT roles which are show what each category does at firm level together with examples for each case will be discussed in the next section. For clarity at the end of the chapter a firm and its ICT applications will be provided.

4.3 ICT roles

General effect: competitive advantage: Many researchers have found that ICT are the most important tool for firms obtaining competitive advantages (Kimberly and Evanisko, 1981; Damanpour and Evan, 1984 in Garrido Azevedo, 2007).
"Competencies are a firm's distinctive abilities, developed as a result of the deployment of combinations of individual resources in unique ways, and through specific organizational routines" (Amit and Schoemaker 1993); (Grant 1991).

"Competencies of a firm are very important and may lead to core competency for a firm which is unique for each firm. Using these unique competencies firms reach superior performance (Eisenhardt and Martin, 2000; Teece et al., 1997 in Tarafdar 2007). It is not easy to imitate ones competency because of two reasons: they are embedded in the firm's culture and routines (Day, 1994 in Tarafdar 2007) and their path dependencies to organizational performance are not always transparent (Barney, 1991; Dierickx and Cool, 1989; Grant, 1991 in Tarafdar 2007).

As wide as its application, ICT technology has diverse impact in a firm. Literature in this field is rapidly growing in number and each focus on different aspect of ICT. To classify this literature,

Communication:

One of the most common and central ICT usage is communication (Johannessen, 1994). This role played by ICT applications implies the facilitation and availability of

communication. Here communication is defined as a two way interaction between individuals.

Communications using ICT technology can involve one or several IT-supported media, such as text, voice, graphics, radio, pictures, and animation. Using different media increases the effectiveness of a message, expedites learning, and enhances problem solving (Bouwman, Hoof et al. 2005).
Examples of ICT applications which fulfill this role are:

- Internal and external networks (such as tcp/ip, LAN or other networks)
- Electronic Mail
- Web-Based Call Centers
- Multimedia call centers
- Electronic boardroom
- Call centers
- Electronic Chat Rooms
- Voice Communication
- Weblogging (Blogging)
- Electronic meeting systems
- Interactive whiteboards – allows different users to simultaneously write on the whiteboard
- Screen sharing software – allows different users to work on one document which is separately visible for every user
- Electronic teleconferencing (video teleconferencing, web teleconferencing)

Communication role of ICT is mentioned explicitly and in numerous studies:

- Sproull and Kiesler define this role as a first level effect of ICT (Sproull and Kiesler 1991). ICT improves internal and external communication, and consequently improves the efficiency. This effect is a first –level effect of ICT. They argue that this role among other first level effects either improve efficiency or productivity. Improvement on internal and external communication caused by ICT applications has also been mentioned by Johannessen et al (1994). This role is also mentioned by Attaran as being critical (Attaran 2003).

- ICT applications in communication are used broadly and very frequently. Barczak and Sultan (2006), Barczak et al observed that simple ICT tools were used more frequently tools in NPD project teams rather than more sophisticated and more complex tools(Barczak, Sultan et al. 2007). Communication tools provided by ICT are usually very simple and thus user friendly and easy to use. Bardhan et al categorize one of the ICT applications at project level (project management) is basic communication technology (BCT) which is appropriate to be used for simple tasks (not complex) for a project.

Effects:

- These ICT applications enhance communication in two ways. They help communication availability tools (so increase communication possibilities and thus increase communication) (Barczak et al, 2007) and also they improve the speed of

communication significantly (Huber, 1990 in Johannessen 1994) (Barczak et al, 2007). They allow all kinds of communication. These different types are shown in the Figure 6 below:

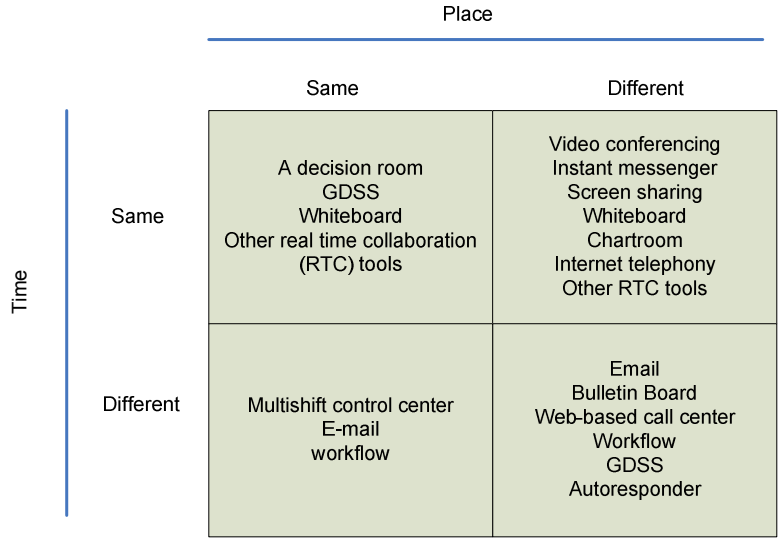


Figure6: different types of communication Bouwman et al (2005)

- Based on Swanson's model Yang Et al (2008) mentions that communication technology such as email, teleconferencing are mentioned to have impact on Product and business administrative process innovation.

- Communication has also been introduced as one of ICT competencies by Gordon and Tarafdar (2007). This competency is mentioned together with collaboration through which they argue that together they influence process innovation. this a cross-sectional study was held in the field of Greek manufacturing firms that apply advanced IT, in order to explore which, how and in what level manufacturing priorities have been adopted.

- faster data collection, processing and faster communication (Garrido, o˜ao et al. 2007).

Coordination:

ICT applications provide coordination among different entities. Internally this coordination is conducted among various departments and even across different units in one department. Externally coordination is provided with other enterprises (firms with in own concern or competitors) or entities along the supply chain such as suppliers and customers.

ICT applications relevant to this role are:

- ICT ordering systems- systems ensuring electronic availability of transaction activities (ordering, purchasing, delivery)
- Electronic after sales service

- Collaborative CRM – customer relationship management which links firm to customers
- The first type of IT system that was developed in the 1980s to improve communications with business partners was electronic data interchange (EDI), which involved computer-to-computer direct communication of standard business documents (such as purchase orders and order confirmations) between business partners.

This role is becoming more and more apparent because the need for coordination has increased. Vertical and horizontal collaboration has been increasing in firms. In order to work efficiently together coordination is essential. It is important to note that coordination helps different entities to be harmonized and have access to common and necessary information. In this way each entity has its own existence, goals and activities separately from the other entities. This does not mean that theses different entities are integrated together. They are only harmonized rather than becoming one entity.
Coordination through ICT application is evident in business processes (Attaran, 2003) (Marjanovic 2005). Business processes include several stages where different entities (units, departments, suppliers or even customers) may be involved in. The larger the number of these entities the more apparent the need for coordination is. ICT has enhanced this coordination through various applications and coordination has been recognized as one of ICT roles.
At project level coordination management has been one of the ICT applications influencing firm's performance which is mentioned by Bardhan R. et al (2007).

Effects:

- Drucker believes that the ICT and networking will be the key to organizational coordination (Drucker 1998).

- They enable collaboration and coordination Bardhan R. et al (2007).

- Coordination is enhanced in speed. (Johansson 1999)

- Facilitation of reuse information (Aral et al. 2006). Reduction on data and data re-entry (Lai et al., 2005 in Garrido et al, 2007; Corso, 2003)

- Since with the use of theses ICT applications different entities will be coordinated, there will be a direct impact on the speed of processes such as knowledge creation.

- Speed of responsiveness is also increased, since the information is harmonize and coordinated more quickly than before (Brynjolfsson 1993) and Garrido et al, (2007).

These two roles are very much related to each other and many authors have mentioned them together as ICT roles such as Boutellier and Prasad. Some have

mentioned enhancing coordination and communication as the fundamental role of IT (T. C. Powell and DentMicallef 1997).

Information:

ICT applications continuously deal with data. It continuously conducts activities on data. These processing are divided into two: first level and second level processing. First level processing includes all the initial activities done to data. ICT applications belonging to this role store, conduct simple operations, protect, update and retrieve information. After receiving data the initial step is to store it (Johannessen 1999; Tarafdar, 2007). Simple operations such as ordering, organizing , categorizing, summarizing, etc follow (Attewell and Rule 1984). In this way the information would be easily accessible and much faster. Being able to retrieve this information is another first level process. Security of the data (protection from viruses, external access, hacking, etc) is essential for any data.

Examples of ICT applications attributed to this role are:

- Stand alone software such as spreadsheet, excel, word, etc
- Databases (including online databases)
- Data warehouses - are repository of an organization's electronically stored data (adopted from Wikipedia). Data warehouses are designed to facilitate reporting and analysis (Inmon 1995).
- Anti-viruses
- Anti-hack
- Backup systems
- Electronic signature
- Data encryption software
- Firewalls

EFFECTS:

- ICT has enabled storage of data. With improvement in this technology the storage capacity has also increased using large data warehouses.

- Security of the data is ensured through ICT applications. This security protects the data against viruses, hack and external access. This issue if of great importance since it is related to confidentiality of information which can not be accessible to all. In addition providing back-ups preserves the data.

- Speed of information retrieval is increased by ICT usage (Huber, 1990 in Johannessen 1994).

- Because data is digitally stored and categorized, information processes will be conducted more quickly (Brynjolffsson, 1993).

- Possibility of knowledge re-use (Corso, 2003)

Automation:

In the informational role I mentioned that there are two types of processing: one is first level and the other is second level. First level processing belongs to informational role while the second level processing is what ICT applications belonging to automation role play. Automation reflects the initial and common definition of technology: to replace labor by technology. ICT applications belonging to this role conduct activities which were done by humans before. In other words automation of workflow is what describes this role best (Barczak et al, 2007). They include complex activities and processes.

ICT applications regarding this role are:

- Decision support systems (DSS) – interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions (adopted from Wikipedia).

- Executive information system (EIS) - enterprise-wide form of DSS. EIS help top-level executives analyze, compare, and highlight trends in important variables in order to monitor performance and identify opportunities and problems. They have high quality graphical displays and easy-to-use interfaces.

- Business Intelligence (BI) - applications and practices for the collection, integration, analysis, and presentation of business information. It is a specific kind of Decision support system (DSS).

- CAD/CAM

- Analytical CRM involves capture and analysis of customer data.

EFFECTS:

- increase in speed of processes This will consequently reduce development costs. It also shortens the time to market (Johannessen, 1999).

- Automation leads to operational excellence (Hackbarth and Kettinger 2004) and operational efficiency Malhotra et al. (2005) and Mark and Monnoyer (2004).

- Problem solving capacity is increased (Thomke, 2006)

Automational role has a direct influence on efficiency (Barczak et al, 2007) such as increase in speed (of any process such as production, delivery, ordering, etc), and reduction of cost, labor. (Kessler and Chakrabarti, 1996 in Johannessen 1999),

Informational and Automation roles can be summarized in "processing data" which is one of the central usage of ICT applications (Johannessen, 1994)

Integration:

ICT tools have the capability to integrate several entities together in order to create a new body. Different business units across the firm or different entities across the supply chain (customers and suppliers) may be integrated into one unit towards a certain goal. This role is of vital importance. I use argument of Vonderembse et al (1997 in Johannessen 1999) to clarify the importance. They state that in the industrial age managers' effort is toward automating specific tasks. In this way they create islands of automation. Then when each island is proved to be working well, they integrated these islands. Now this approach is argued that this does not lead to an efficient result of automation. What is important is to focus on integration initially before separate automations. Then with careful analysis the automation decisions should be taken.

- MRP (material requirements planning, and then manufacturing resource planning) is a software based production planning and inventory control system used to manage manufacturing processes. Objectives of MRP:
    - Ensure materials and products are available for
    - Production and delivery to customers.
    - Maintain the lowest possible level of inventory.
    - Plan manufacturing activities, delivery schedules and purchasing activities.

- CIM (computer-integrated manufacturing) is used for manufacturing processes which includes:
    - means for data storage, retrieval, manipulation and presentation;
    - mechanisms for sensing state and modifying processes;
    - Algorithms for uniting the data processing component with the sensor/modification component.

MRP and CIM are not very common now bit they are the origins of other enterprise systems which are more common now. These systems are explained below.

- ERP- Enterprise Resource Planning is a cross-functional and enterprise wide business support system. All functional departments that are involved in operations or production are integrated in one system. In addition to manufacturing, warehousing, logistics, and information technology, this would include accounting, human resources, marketing, and strategic management. Examples of modules in an ERP which formerly would have been stand-alone applications include: Manufacturing, Supply Chain,

Financials, Customer Relationship Management (CRM), Human Resources, Warehouse Management and Decision Support System.

- ERP II – is an open ERP architecture of components. ERP II besides focusing on enterprise-wide information usage, it also focuses on delivering information to the individual. This was not primarily possible with ERP.

- Enterprise Application Suite (EAS) – is similar to ERP but uses ordinary Internet browsers as clients.

- Transaction Processing System (TPS) – This system manages all the transactions of a firm. It links different departments together. It is focused only on transactions of firm and not multiple activities (like the above systems).

- Collaborative CRM deals with all the communication, coordination, and collaboration between vendors and customers. It links the firm to customers.

EFFECTS

- Because different entities are integrated, knowledge re-use is done more efficiently.

- Knowledge integration is a result of ICT usage from this role (Johannessen, 1999). This notion is of vital importance for companies since knowledge integration within companies may result in sustainable competitive advantages (Grant, 1996).

- In a business process not only creating knowledge occurs but also different body of knowledge is combined together. Integration role enables recombination of knowledge (Corso, 2003). This recombination s done more efficiently than when each unit was performing separately.

Examples of all the roles except the last role (integration) were more or less common and so they were easy to grasp the meaning of each role. This might nit be the case for the integration role. Therefore for the sake of clarity I will give an example of ERP application used in a firm.

Bigfoot Industries Inc. was established in 1978 (www.bigfootrv.com) and has provided the Recreational Vehicle, Camper and Pull Trailer industry with state-of-the-art RV equipment. IT manufactures 800 make-to-order units a year. Duplicate data entry was carried out to standalone sales order, MRP and financial systems. There was no data integrity and the firm lacked system integrity. This led to creation of excess inventories, production delays and customer shipping delays. The MRP system and the Sales Order Entry system adversely were incompatible and influenced the purchasing and therefore the inventory errors caused problems like delays for production and shipments to customers.
Now Bigfoot has implemented an ERP system integrating their sales, finance, materials and production information. As a result duplicate data entry problem is solved.

Any information is now accessible through one source. Other results of ERP implementation are: operational benefits, ability to streamline business processes, etc. Response to shortages is much quicker than before. In short, Bigfoot has connected its different business units using ERP and it is now essential for its business.

You can see the conceptual model on the next page in Figure 7.

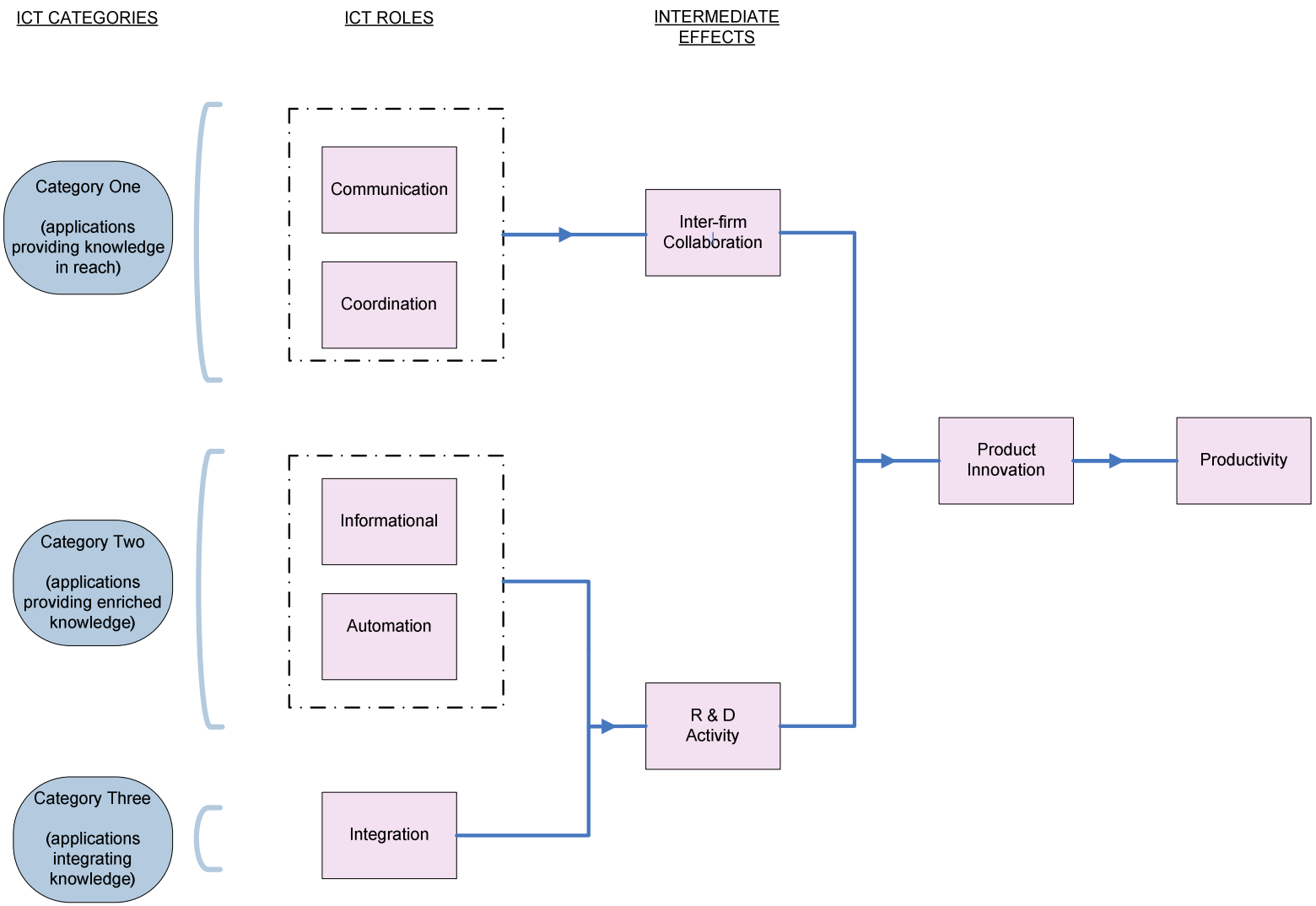


Figure 7: Conceptual Model

The left hand side of the model namely ICT categories and their roles have been discussed. The following section will cover the intermediate effects (collaboration and R&D), product innovation and productivity.

4.4 Intermediate effects

4.4.1 Inter-firm Collaboration

According to the literature review conducted in the previous chapter (chapter 2) I introduce two intermediate effects between ICT usage and innovation: inter-firm collaboration and R&D activity.

The first ICT category's primary effect is on collaboration. Both communication and communication enhance collaboration. Collaboration in the model presents two kinds of collaboration : internal and external, internal collaboration is conducted with enterprises that are within firm's concern (such as its daughter) and external collaboration is defined with competitors, suppliers, customers, public and private institutions and basically any external group or entity (external to firm).

ICT tools that enhance collaboration are software products that basically support groups of people who share a common task or goal and who collaborate on its accomplishment. These applications are called Groupware. Groupware use networks to connect people, even if the people are in the same room. Examples of groupware are Electronic Meeting Systems, Electronic Teleconferencing (video teleconferencing, web conferencing). Groupware are divided into two subgroups of tools: real-time and virtual. Real-time collaboration Tools (RTC) bridge time and space to make decisions for collaboration on projects. RTC tools support synchronous communication of graphical and text-based information. On the other hand Virtual collaboration (e-collaboration refers to the use of digital technologies that enable organizations or individuals to collaborate virtually. These tools facilitate collaboration in virtual environments.

- Web-based systems (many using XML) deliver business applications via the Internet. Using browsers and the Internet, people in different organizations communicate, collaborate, access vast amounts of information, and run most of the organization's tasks and processes.
    - These systems became the basis for collaborative commerce.

ICT Communication tools enable new communication channels through which firm can collaborate with its partners. For example internet alone provides numerous opportunities such as email, voice conferencing, etc. Through ICT distance and time boundaries diminish. Partners across the globe can communicate easily... All four kind of communication mentioned before synchronous vs. asynchronous and distributed vs. none distributed. Not only the speed of the process is substantially increased, but the cost for knowledge transfer also reduces. Not only the enhancement in information exchange is important but also the coordination among the contributing partners is

crucial. ICT usage has so much influence on collaboration that one of the ICT competencies proved to be developed by ICT usage is Collaboration (Tarafdar, 2007).

Communication and coordination in an organization enhances collaboration because they blur the boundaries and create a virtual organization (Bouwman, Hoof et al. 2005).

ICT not only enhances collaboration (through communication and coordination capabilities) but it also reduces cooperation costs. In addition it increases the possibilities of potential relations through enabling direct interaction with partners without increase in cost (Bertschek and Kaiser 2004).

4.4.2 R&D Activity

Another intermediate defined in the conceptual model is Research and Development (R&D) activity. R&D is a crucial component of innovation, particularly product innovation. Traditionally the boundaries of R&D were very limited to closed research and limited interaction with environment in order to generally identify customer needs and market. These boundaries have been removed. Different kinds of interaction with environment, customers, suppliers, competitors and research institutes are continuously conducted. The data should therefore be continuously stored, updated and retrieved. To be able to reach optimum efficiency and to be able to recombine different bodies of knowledge ICT helps process and integrate different bodies of knowledge.

In context of product innovation various automation tools have enhanced the R&D process for product development. Virtual Prototyping and Computer Aided Design (CAD) have been influential.

Several ICT applications for example CRM integrate customer systems to that of firms'. This can be considered as an external collaboration between firm and customer. We can see that integration is influential here. But according to my studies, with regard to R&D and in the context of product innovation, integration's role is stronger and more apparent. Integration in R&D has a broader meaning than in collaboration. In R&D it involves more than two parties. During a New product development several internal and external entities' information is needed along the process. While in collaboration only two parties can be involved and their system integrated. Corso recognizes three-dimensional computer-aided design (3D CAD), as one of the tools supporting integration rather than as a tool adopted in the NPD process since 3D was used to support technological coordination especially with customers (Corso et al., 2001b, 2000).

4.5 Product Innovation

ICT usage leads to different competencies. One of them is recognized as "innovation" (Tarafdar, 2007). Therefore ICT usage leads to innovation which is realized as a competency and is thus very valuable for the firm.

One of the project competencies for innovation is customer and market relevance of the outcome (Balasubramaniam et al. 2000, Zeithaml and Bitner 1996 in Bardhan R. et al 2007). This is managed through the ICT application of all three categories. Through communication and coordination customer collaboration is enabled and enhanced while the data is stored and processed (e.g. using prototyping and design tools) in an integrated system linking different business systems of a company together.

Information sources of innovation is mainly (almost 60%) gained through intra firm relations (Pavitt, 1984) according to study of 2000 British firms Britain since 1945. This shows the importance of collaboration for innovation. In addition most technological knowledge is the specific to firms and cumulative in development rather than general information which could be imitable. This reveals the importance of combining and recombining of knowledge used in R&D. It further makes the ICT roles belonging to all three categories more apparent. The unique combination of knowledge is enhanced through various ICT application usages.

Generally ICT has been related positively to innovation by several other authors (Benko and McFarlan, 2004; Cooper et al., 2004; Walsh, 2001; Theodoroua, 2008)

4.6 Time lags

Along with the productivity paradox studies and explanation for this paradox was given by Brynjolffsson introducing the time lag issue. According to his studies ICT investments don't pay off immediately. It takes time for ICT investment to impact productivity and thus judgment on productivity should not ignore the time lag.

These time lags are due to due to learning and adjustment needed after a technology is adopted or invested in. Any kind of investment in technology (not necessarily) ICT, may result in time lag before it effects productivity.

Relatively investments in different innovation actives may result in such time lag. The time lag for innovation investment has not been covered in literature. But possibility of the existence of this time lag has motivated me to explore it.

Innovation activities include:

- Intramural R&D
- Extramural R&D
- Acquiring knowledge
- Acquiring equipment and machinery

Each of theses activities require time (the adjustment time is relatively larger for some of the activities). Conducting R&D and investing in R&D may not immediately pay off immediately. Acquiring knowledge does not need time and can be done in short period of time but implementation of this knowledge certainly needs adjustment time. When a new equipment and machinery is bought, training and organizational change cause the time lag.

5 Chapter five: Research hypotheses

The conceptual model was presented in the previous chapter. Now to test this model, several hypotheses will be designed in this chapter. These hypotheses are designed to test different relations of the new model. Each hypothesis with the rationale behind it is provided.

5.1 Research Hypotheses

The designed hypotheses aim at different part of the model. In order to be able to test different parts of the model, hypotheses were built on the basis of the relations between the modules. In addition general hypotheses testing the relation between several modules are also presented in order to provide a more general view. However I have to not that no hypotheses test the inter relation between each set of modules. For example the interrelation between the ICT roles or the interrelation between the intermediate effects is out of the scope of this paper and thus no hypothesis is built on the basis of these interrelations.

Not all the relations in the model are tested, partially due to data constraint and partially because they were not aligned with the interest of this paper.

H1 and H2 test the relation between ICT usage belonging to different categories of ICT (category one, category two, category three). For collaboration effect the relevant ICT category is further broken down to their composed ICT roles. In this way H1.1 and H1.2 are formed.

Hypothesis H3, tests the contribution of intermediate effects on product innovation. H4 is more detailed and tests the link between category one, collaboration and product innovation.

Next set of hypotheses ranging from H5 to H7 are related to productivity. H5 is designed to test the relation between innovation and intangible effects of productivity (H5.1). These intangible effects are broken down to production related and product & market related effects which for hypothesis H5.2 and H5.3 relatively. H6 tests the relation of innovation and intermediate effects to productivity (intangible). H7 tests the possibility of time lags between innovation and labor productivity (financial value).

Finally H8 tests the contribution of ICT usage and intermediate effects to productivity. This will give a general view about whether ICT enhances productivity.

ICT and intermediate effects

Different ICT applications have different impacts. Communication and coordination impacts of ICT are predicted to influence firm's collaboration. The interaction between various collaborating partners is fundamentally supported by the communication channels between them and the level of coordination. ICT applications support and enhance communication and coordination. Thus it is expected that ICT applications

belonging to category one to support collaboration. This hypothesis is further broken down to the role components. So not only are we interested in investigation of category one contribution to collaboration but also in contribution of each role (composing category one) to collaboration.

H1: Category one ICT applications are related to collaboration

> *H1.1: Category one ICT applications are positively related to collaboration*
>
> *H1.2: Communication role and coordination role (roles of ICT applications from category one) are positively related to collaboration*

Beside category one ICT applications, there are applications which regard to automation and integration role of ICT. ICT automates processes and integrates knowledge internally and externally. R&D is closely related to data processing (automation) and knowledge integration as mentioned before. It is predicted that ICT usage from Category two and three applications contribute to R&D.

H2: Category two and three ICT usage are positively related to R&D

Product innovation

As mentioned before in the literature two main factors influencing firm's product innovation are collaboration and R&D. This relation is tested by the following hypothesis:

H3: Intermediate effects contribute positively to product innovation

Collaboration is one of the intermediate factors and according to literature is very important for product innovation. On the other hand ICT usage of category one enhances the communication and coordination effect needed for an efficient collaboration. It is interesting to test the ICT usage of category one (communication and coordination role) and collaboration regarding innovation and to see whether they contribute positively to product innovation.

H4: category one ICT usage and collaboration contribute positively to product innovation

It is interesting to test the contribution of product innovation productivity because of the contradictory result from other research.

H5: Product innovation and productivity

H5.1: Product innovation contributes positively to productivity (intangible effects)
H5.2: Product innovation contributes positively to productivity (production related effects)
H5.3: Product innovation contributes positively to productivity (product & market related

Productivity

Researchers have suggested studying innovation regarding the productivity paradox. ICT is thought to initially influence innovation and consequently have impact on productivity. Now what I am interested in is to test whether product innovation and the intermediate effects are positively related to productivity.

H6: Product innovation, intermediate effects and productivity
H6.1: Product innovation and collaboration contributes positively to productivity
H6.21: Product innovation and R&D contribute positively to productivity
H6.1: Product innovation and collaboration & R&D contribute positively to productivity

The intermediate effects influencing innovation may influence productivity as well. Contribution of each intermediate effect together with innovation as well as contribution of both on intermediate effects together with innovation is predicted to be positive.

The time lag between technology adoption and productivity is well apparent in the literature. Since I am using innovation as an intermediate construct I am willing to explore the time lag between innovation and productivity. Technology adoption with regard to innovation may cause a time lag in showing its effects on productivity.

H7: Product innovation contributes to productivity after a time lag

This research was motivated initially by productivity paradox. In order to deepen the understanding about this topic the mechanism were introduced as intermediate effects, which are believe to have positive effect on productivity. To test the simultaneous usage of ICT and intermediate effects on productivity, I will test whether ICT usage (in all categories) together with the intermediate effects influence productivity.

H8: ICT usage together with the intermediate effects contribute positively to productivity

6 Chapter six: Data Analysis

This chapter discusses the data which will be used for analysis. Primarily explanation of how the dataset is constructed will be provided. Then the tools and methods used for analysis are introduced. A section is also dedicated to the methodology regarding the regression models. Data reduction which is operated on the data is discussed in the last section of this chapter.

6.1 Data

Data Sources

From the early stage of my research I started to construct a relevant and consistent database for my research. I had access to various datasets on ICT, Innovation and Productivity Statistics through Netherlands Central Bureau of Statistics (CBS). Each of the surveys was sent to multinational companies within the Dutch company during the time span of about ten years[2]. Because I was highly motivated to conduct a sound analysis and as much as possible careful analysis of ICT usage relation to innovation and productivity, I opted to construct a panel data including all the above datasets. This also gave me the opportunity to consider the existence of possible time lags for productivity.

Panel Data Definition

In order to understand what panel data is I will define two types of data: cross sectional and time series:

Cross sectional Data: Consist of observations on multiple phenomena at one instance in time. This data set has only one dimension which is the dimension of phenomena.

Time series data: contain observations on a single phenomenon observed over multiple time periods. This dataset is also one dimensional but its dimension is time.

Panel data: is a combination of the above definitions. It consists of observations on multiple phenomena observed over multiple time periods is called panel data. Panel data is known to have two dimensions (multiple phenomena, over several time periods).

Below you can see two examples of panel data in Table 6. The first one (on left) is balanced panel data and the second (on right) is unbalanced. In the balanced data the internal network of every firm is observed for every year (2000 and 2001). But in the second data set for the firm 2 the internal network is only observed for one year. Therefore this is an unbalanced panel data.

[2] The range of the years is different for each questionnaire; for ICT 1995-2004, Innovation 1996-2004 and Productivity Statistics 1994-2004.

Firm id	year	Internal network
1	2000	0
1	2001	1
2	2000	0
2	2001	1

Firm id	year	Internal network
1	2000	0
1	2001	1
2	2000	0
3	2000	0

Table 6: balanced (left) unbalanced (right)

The panel data set I have constructed is an unbalanced panel. Because of the long period range which the data is constructed from, a number of firms' data for some measures is not available for every single year.

Surveys

As mentioned before, I have constructed an extensive panel data using three different questionnaires over the time span of about 10 years from which information about Innovation, ICT and Production Statistics of Dutch companies were collected. The questionnaires used are:

CIS questionnaires:

CIS stands for Community Innovation Questionnaire. CIS questionnaires include five different waves of CIS2, CIS 2.5, CIS 3, CIS 3.5 and CIS4 which are mainly centered on the concept of innovation. Each questionnaire is specific for a time span of two years. Therefore every two years a new CIS questionnaire was developed and sent to Dutch firms in the Netherlands. The first CIS questionnaire (CIS2) was specific to period 1994 to 1996 and consequently CIS 2.5 for 1996-1998, CIS 3 for 1998-2000, CIS3.5 for 2000-2002 and CIS 4 for 2002-2004. These questionnaires were developed over the years. A range of variables such as innovation effects have been added to the original questionnaire. Also in the early versions of the questionnaire product and service innovation were completely distinguished were as in the recent waves, product and service innovation are considered together.

Generally CIS questionnaires include questions about different types of innovation, innovation activities, collaboration, information sources, and hampering factors for innovation and also include information about the firm characteristics and its financial performance.

	CIS 2	CIS 2.5	CIS 3	CIS 3.5	CIS 4
year	1994-1996	1996-1998	1998-2000	2000-2002	2002-2004

ICT questionnaires:

ICT questionnaires cover the time span of 1995 to 2004. These include questions about different ICT applications used in a firm, ICT employees, as well as general information about the firm characteristics and financial performance.

	ICT
year	1995-2004

PS questionnaires:

PS stands for Productivity Statistics and the PS questionnaires cover the time period of 1993 to 2004. They include questions concerning the outputs (production) and inputs (production factors) of Dutch companies. These too, include information about firm's characteristics.

PS questionnaires were different for different sectors. The following table shows the various sectors. As you can see the information available for some sectors were not available for the whole period between 1993 and 2004.

	PS						
year	1993-2004	1993-2004	1995-2004	1993-2004	1993-2004	2001-2004	2000-2004
Sector	Building Construction	Retail	Service	wholesale	industry	Development	Transport

ABR database: This is a database about registrations of firms. Four variables regarding the registration of firms were used from this database.

Panel Dataset Construction

Construction of the data was done in parallel with the theoretical study, starting in the early stage of the research. CIS, ICT and PS datasets for various years were to be linked together to form the final panel database. CIS datasets were used as the reference point. The reason is because innovation is the link between ICT and PS. ICT investments lead to innovation and PS datasets show this effect later on. Thus for each CIS dataset relevant ICT (datasets before the CIS year) and relevant PS (datasets after the CIS year) were considered.

1. harmonizing Data Sets

The first step was to harmonize different datasets for each set of questionnaires. Harmonizing was done for CIS and PS datasets. The ICT dataset was harmonized by CBS and a longitudinal data set was available.

CIS: there were five different datasets including different variables and different number of observations. These databases were to be harmonized across different years. Thus I

had to make sure that the number of variables, order of the variables and their content (ranking, unit of measurement, definition) were identical in all five databases.

CIS Wave	Number of variables
2002-2004	206
2000-2002	129
1998-2000	202
1996-1998	336
1994-1996	291

Original CIS datasets

CIS Waves (harmonized)	Number of observations	Number of variables
2002-2004	10853	98
2000-2002	10638	
1998-2000	10750	
1996-1998	13465	
1994-1996	10664	

Harmonized CIS datasets

PS: PS datasets included longitudinal datasets which were provided separately for different sectors of construction wholesale, retail, industry, services, development tracking and transport. The first step here was to extract data from each sector for specific years (each year from 19953 to 2004). Then the PS datasets were produced which for each year included all the sectors. The final step in this section was to harmonize the datasets which were now constructed according to year. This was done by careful checking of number of variables, order of the variables and their content (ranking, unit of measurement, definition) which had to be identical in all five databases.

PS wave	Construc-tion (bouw)	retail (detailhandel)	Services (dienst)	Wholesale trade (groothandel)	Industry (industrie)	Develo pment tracking (Speuron twikkeling)	transport
2004	4298	3003	18772	7149	9778	225	4685
2003	6217	5250	20241	9839	10718	205	4799
2002	5132	4661	19131	9096	10270	177	4748
2001	6267	5265	16350	9281	10659	208	4575
2000	5414	4637	2491	7959	8023	-	4234
1999	9318	9886	23244	5709	11262	-	-
1998	90334	9513	23654	5368	14219	-	-
1997	7440	9697	21922	12456	9460	-	-

1996	9279	9673	21751	4722	11220	-	-
1995	6502	11117	18857	12612	6315	-	-
1994	6688	9762	-	11908	6365	-	-
1993	6744	7598	-	11963	6483	-	-

Number of observations in different sectors

Original PS datasets

PS (harmonized)	Number of observations	Number of variables
2004	47910	103
2003	57269	103
2002	53215	103
2001	52605	103
2000	42758	103
1999	59416	103
1998	61788	103
1997	60975	103
1996	56645	103
1995	55403	103
1994	34723	103
1993	32788	103

Harmonized PS datasets

Note: some sectors did not have information for specific years. These sectors included services which were only informational for 1993 till 2004, speurontwikkeling for 2001 till 2004 and transport for 2000 till 2004.

2. Linking datasets horizontally:

after CIS, ICT and PS datasets were separately harmonized for each year, I joined them horizontally together. Because there were five waves of CIS survey and as mentioned before I used the CIS datasets as reference point, I created 5 separate datasets which each were linked databases of CS, ICT and PS. Every CIS dataset was linked to 6 PS datasets and 5 ICT data sets. In other words for each CIS wave I chose 6 PS datasets of the same CIS year and after, while the linkages to 5 ICT datasets were made the ICT datasets of same CIS year and before. Before linking these datasets I made sure no variables existed with the same name. Otherwise the variables with the same name in two different datasets would have replaced each other.

CIS 04	ABR	PS 04	PS 03	PS 02	ICT 04	ICT 03	ICT 02	ICT 01	ICT 00

CIS	ABR	PS	PS	PS	PS	PS	ICT	ICT	ICT	ICT	ICT

02		04	03	02	01	00	02	01	00	99	98

CIS 00	ABR	PS 03	PS 02	PS 01	PS 00	PS 99	PS 98	ICT 00	ICT 99	ICT 98	ICT 97	ICT 96

CIS 98	ABR	PS 01	PS 00	PS 99	PS 98	PS 97	PS 96	ICT 98	ICT 97	ICT 96	ICT 95

CIS 96	ABR	PS 99	PS 98	PS 97	PS 96	PS 95	PS 94	ICT 96	ICT 95

3. Linking datasets Vertically:
4.

Now that the datasets of CIS, ABR, ICT and PS are linked to each other according to CIS dataset (using as reference for it's year and also firms or number of observations), I took the final step to complete the panel dataset. I appended all five rows i.e. each row was placed on top of the next row. Before doing so I made sure the databases with the same time lag to be place exactly under each other. As you can see in the above rows, the rows have different lengths and differ in number of datasets. In other word there are some datasets missing. I created these empty datasets (each variable is placed missing). Then I appended the rows together.

T0=2004

		T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 04	ABR	PS 04	PS 03	PS 02	ICT 04	ICT 03	ICT 02	ICT 01	ICT 00

T0=2002

		T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 02	ABR	PS 04	PS 03	PS 02	PS 01	PS 00	ICT 02	ICT 01	ICT 00	ICT 99	ICT 98

T0=2000

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 00	ABR	PS 03	PS 02	PS 01	PS 00	PS 99	PS 98	ICT 00	ICT 99	ICT 98	ICT 97	ICT 96

T0=1998

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3
CIS 98	ABR	PS 01	PS 00	PS 99	PS 98	PS 97	PS 96	ICT 98	ICT 97	ICT 96	ICT 95

T0=1996

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1
CIS	ABR	PS	PS	PS	PS	PS	PS	ICT	ICT

96		99	98	97	96	95	94	96	95

T= 0: year of CIS is the t=0 and the reference.
T= p* show the years *after* the reference year
T= [1 or 2or 3 or 4] show the years *before* the reference year

T0=2004

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 04	ABR	PS empty	PS empty	PS empty	PS 04	PS 03	PS 02	ICT 04	ICT 03	ICT 02	ICT 01	ICT 00

T0=2002

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 02	ABR	PS empty	PS 04	PS 03	PS 02	PS 01	PS 00	ICT 02	ICT 01	ICT 00	ICT 99	ICT 98

T0=2000

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 00	ABR	PS 03	PS 02	PS 01	PS 00	PS 99	PS 98	ICT 00	ICT 99	ICT 98	ICT 97	ICT 96

T0=1998

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 98	ABR	PS 01	PS 00	PS 99	PS 98	PS 97	PS 96	ICT 98	ICT 97	ICT 96	ICT 95	ICT empty

T0=1996

		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 96	ABR	PS 99	PS 98	PS 97	PS 96	PS 95	PS 94	ICT 96	ICT 95	ICT empty	ICT empty	ICT empty

Note: For appending the datasets, the datasets of the same time lag should be positioned on top of each other. Some datasets were not available for example PS is only available till 2004 and this in the first "row" of datasets which start from CIS 02-04, the first three datasets were not available. In this case empty datasets (all variables equal to missing) were constructed to be placed in the relevant place.

To have an overview o f the whole panel data, see Table 7 below.

PANEL OVERVIEW		Time lag axis									
		T=p3	T=p2	T=p1	T=0	T=1	T=2	T=0	T=1	T=2	T=3	T=4
CIS 04	ABR	PS empty	PS empty	PS empty	PS 04	PS 03	PS 02	ICT 04	ICT 03	ICT 02	ICT 01	ICT 00
CIS 02	ABR	PS empty	PS 04	PS 03	PS 02	PS 01	PS 00	ICT 02	ICT 01	ICT 00	ICT 99	ICT 98
CIS 00	ABR	PS 03	PS 02	PS 01	PS 00	PS 99	PS 98	ICT 00	ICT 99	ICT 98	ICT 97	ICT 96
CIS 98	ABR	PS 01	PS 00	PS 99	PS 98	PS 97	PS 96	ICT 98	ICT 97	ICT 96	ICT 95	ICT empty
CIS 96	ABR	PS 99	PS 98	PS 97	PS 96	PS 95	PS 94	ICT 96	ICT 95	ICT empty	ICT empty	ICT empty

Table 7: Panel data overview

The number of observations for each row equals to the number of observations of CIS because we used the CIS data as reference. The command used to join the datasets in Stata (for the first row) is:

Joinby be_id using cis04.dta, unmatched (master)

The numbers of observations for each row are shown in the table below:

	Number of observation
Row 1 (starting from cis04)	10853
Row 2 (starting from cis02)	10638
Row 3 (starting from cis00)	10750
Row 4 (starting from cis98)	13465
Row 5 (starting from cis96)	10664

The following table shows the number of variables for each row.

	CIS	ABR	PS	ICT
Number of variables	98 (including firm id)	4	9	65

Each row consist of 12 datasets from which 1 is CIS, one is ABR, six PS dataset and 5 ICT datasets. Thus:
Number of variables for each row = 98 + 4 + (65*5) + (9*6) = 481

PANEL DATA	
Number of observations	56,370
Number of variables	481

Data Consistency

Various approaches were taken to ensure the consistency of data. Because many changes have been made to a large number of variables, it is not possible to mention all the changes here but I have chosen examples from CIS datasets.

- Because the questionnaires evolved through time, some questions simply did not exist in previous waves. Instead of excluding these variables I created these variables for the datasets that did not have them and of course attributed "missing" as value to them.

- Consequently some questions were considered redundant or irreverent in the recent questionnaires and thus were omitted. In theses cases because the variables only existed in one or two questionnaires (out of 5, because I am taking CIS as an example), the variable was omitted.

Same variables but in different CIS waves had different values. For example type_rd is a variable that shows what kind of R&D does the firm conduct. It could be permanent, or incidental. In CIS 96 and 98 three values of 1:permanent, 2:incidental, 3:no R&D were assigned for each firm while in other waves only two options of incidental and permanent were given. In addition the number attributing to permanent is 1 in waves 96 and 98 while this option is attributed to number 1 in other waves. Therefore two steps should be taken. First the values attributed to constructs were harmonized to permanent and incidental. Then the same value was given to permanent option in all waves. Tables below show the differences in this variable:

CIS 1996 and 1998

Variable	Description	Value
Rd_type	Type of R&D	1:permanent 2:incidental 3:no R&D

CIS 2000, 2002, 2004

Variable	Description	Value
Rd_type	Type of R&D	0:incidental 1:permanent

Solution: I created all values according to CIS 1996 and 1998. Otherwise I had to eliminate the value "3" by which a lot of the data would be lost. And of course I had to change the value 0 to 2 and value 1 would stay the same.

- Some variables are distinguished in detail in some datasets and not in the other. For example in CIS 1996 and 1998 innovation in services and products are distinguished while in the other surveys product and services are always considered together throughout the whole questionnaire. For solution to this problem, I integrated the service part of questions in 1996 and 1998 with the product part.

- In some cases same variables were measured on different scales. For example turnover in 2002 is measured as percentage from 0 to 100 while in all other questionnaires it is measures as percentage but on a scale of 0 to 1.

- Logical relations and simple mathematical operations between different variables were also checked. For example number of R&D employees should not exceed total number of employees. Or if a firm does not have R&D activity then its R&D expenditure should be zero.

- One of the main issues I came across during the process of panel data construction was the fact that in STATA missing value is treated as infinity. This change had to be made to the variables that were constructed while ignoring this issue. Every combination of several variables would go wrong by ignoring this assumption. I find it necessary to explain this issue since ignoring this issue leads to a biased data.

  For creating a new variable out of two other variables, a comparison is made between the two and according to certain if conditions a value is attributed for the new variable. In this comparison "missing" would be treated as infinity. Thus in any mathematical comparison missing would be regarded as larger than numeric value. So if one of the variables is missing, the new variable would also be stated as missing. And in this was I would loose one observation. To prevent this I added if conditions distinguishing whether either of the variables to be combined is missing or not. I attributed the missing value (to the new variable) only if both values were missing. If only one variable was missing, the value of the "not missing" variable would be placed.

- In the descriptive statistics of all the variables, some variables had illogical values. For example:

Variable	Obs	Mean	Std. Dev.	Min	Max
total_expend	14485	1321245	1.85e+07	-.0099759	1.16e+09

The minimum amount for total expenditure is a negative number. This is logically not true. But with the next command I found out that there were only 27 firms out of 56,370 firms that had a negative number for this variable. Therefore the number of firms with this problem is very limited. This problem could be a typing error, measurement error, etc. There are other variables with similar problem and in every case the number of the firms is extremely small compared to the number of the observations in the sample. You can find a list of these variables in the email attachment.

Tools and methods

After the collected data were completely cleaned, statistical and econometric methods were used to construct the model, validate the model, and test the hypotheses. The main statistical packages used were Stata 10 and SPSS 14 for Windows. Initially I used SPSS but gradually and according to the investigation that I did, I realized that Stata is more powerful to be used for Panel data. Therefore I started mastering Stata. But I used both of these softwares because each was powerful in different operations. For example factor analysis was done in SPSS while the regressions and error tests were done in Stata.
The models and methods employed in different parts of the empirical analysis of the research are discussed in the following chapters.

6.2 Methodology

Panel data consists of repeated observations over the same units (in this case firms), gathered over a number of periods. The general linear model used for panel data is the following where index I is used for each firm and index t is used for time period:

$y_{it} = \beta_{it} x_{it} + u_{it}$ (1)

β_{it} measures the partial effect of x_{it} in period t for unit i. This model is very general and not suitable for analysis. Therefore more structure should be given to β_{it}. In addition x_{it} may be correlated with u_{it}. But the central assumption for regression is that the X variable and the error term are uncorrelated (exogeneity). Endogeneity (when x variable correlates with the error term) results in biased regression estimates. Endogeneity is considered the fundamental problem.
Two different approaches lead us to a better structure and improve exogeneity. The final models produced are: fixed effects model and random effects model. These regression models are based on the following strategy:

We decompose the error term into two components of: firm-specific error v_i and an idiosyncratic error ε_{it}. Thus we have:

$u_{it} = v_i + \varepsilon_{it}$ (2)

As you can see v_i does not include an index for time. It does change over time, where ε_{it} varies over time.

The standard assumption is that β_{it} is constant for all i and t except the intercept term(verbeek 2006). Now if we combine the two equations of (1) and (2) we can conclude:

$y_{it} = \beta x_{it} + v_i + \varepsilon_{it}$ (3)

In this way v_i captures all the effects of variables peculiar to i-th firm which are constant over time. In standard ε_{it} is independent and identically distributed over firms in time with mean zero and variance σ^2_{ε}.

In panel data, the data provides two kinds of information one about between subjects (firms) and one about within subjects (firms). Therefore two sources of variances can be derived from a panel data. Whether the focus is on within variance or on between variance different estimators can be constructed. Two common and suitable estimators will be explained below: fixed and random effects estimators.

Fixed effects estimation:

Fixed effects model focuses on the answer to the following question:
What is the effect of variable x when variable x changes within subjects (firms) over time?

The variance analyzed in this model is thus the within variance.

Fixed effect is derived from equation (3) with one assumption: only if we treat the v_i as N fixed unknown parameters. The logic behind the fixed effect estimator (FE effect) is explained here. We start from the error component model, equation (3):

$y_{it} = \beta x_{it} + v_i + \varepsilon_{it}$ (3)

If this equation is averaged over time for each i (between transformation):

$\bar{y}_{it} = \beta \bar{x}_{it} + v_i + \bar{\varepsilon}_{it}$ (4)

With subtraction of (3) and (4) for each t (within transformation) we have:

$y_{it} - \bar{y}_{it} = \beta (x_{it} - \bar{x}_{it}) + \varepsilon_{it} - \bar{\varepsilon}_{it}$ (5)

As you can see v_i component of the error term has disappeared and thus we don't need the assumption that v_i is uncorrelated with x_{it}. Time constant heterogeneity is not a problem anymore. This model can now be estimated by FE estimator (pooled OLS).

We subtracted the between variation and only the within variation is left. This is why FE estimator is also called within estimator.

Disadvantage of this model is that it includes only time variant variables.

Random effect estimation

Random effects model focuses on the answer to the following questions:
What is the effect of variable x when variable x changes within subjects (firms) over time?
What is the effect of variable x when variable x changes between subjects (firms) over time?

Therefore this model focuses on both within and between variances.
One advantage of this model over fixed effect is that random effect includes time variant variables as well as time invariant variables.

Here we assume the intercept of firms are different but drawn from distribution with mean μ and variance σ^2. These drawings are independent of x_{it}. This results in random effects model where individual effect (v_i) are assumed to be random. In order to understand the logic behind the random effect estimator we start from error component model (3) but including a constant now.

$y_{it} = \beta_0 + \beta x_{it} + v_i + \varepsilon_{it}$ (6)

In the above equation v_i is random. Using pooled-GLS estimator leads us to random effect (RE) estimator. RE estimator combines within and between estimators.

In short:
FE estimator (within estimator): exploits the within dimension of data i.e. differences within individuals. X variables should be exogenous (uncorrelated with ε_{it}) but there is no restriction for correlation between v_i and x_{it}.

RE estimator (EGLS estimator): combines within and between dimensions of the data in an efficient way. One requirement for random effect estimator is for individual error terms to be random variables and have normal distribution.

Which model to choose from?

These two estimators have their own advantages and disadvantages.
Disadvantage of FE estimator:

- It works only if x_{it} and v_i are uncorrelated otherwise FE estimator would be biased.

- FE estimator does not include time invariant variables. On the other hand RE estimator includes time invariant variables such as sector and the effect of such variable can only given by RE.
- Fe focuses on within variance while RE considers both within and between variances.

Disadvantage of RE:

- It does not solve the problem of heterogeneity and only works if there is irrelevant unobserved heterogeneity.

- Error terms are required to have normal distribution and to be treated as random variables, whereas this requirement is not needed for FE.

Despite the disadvantages of each estimator, each estimator is suitable for specific regression. In order to decide which estimator to use, I used the Hausman Test for each regression.
The null hypothesis for Hausman test is:

H_0: Coefficients estimated by efficient random effects estimator are same as those estimated by consistent fixed effects estimator.

After running regression with both estimators and saving the estimates, I conducted the Hausman test. It is common for P-value or Prob>chi2 larger than 0.05 to use Random Effect estimator.

6.3 Data Reduction

Several questions in the questionnaire can lead us to determine the various constructs of the conceptual model.

Factor analysis consists of several statistical techniques which range from confirmatory techniques to pure exploratory procedures. This technique was invented by Spearman (1904) and helps to explain the variability among a larger number of observed random variables in terms of a smaller number of unobserved random variables or factors. Because a larger number of variables are reduced to smaller number of variables, factor analysis is known as a data reduction technique. There are two methods for this reduction: exploratory (EFA) and confirmatory (CFA).

In EFA any indicator could be attributed to any factor. Therefore there is no underlying theory to choose certain number of indicators for creating the factors . Here the factor analysis finds out which indicators create suitable factors and can be grouped together. Thus method is used when the primary goal is to summarize the data according to factor loadings provided by the factor analysis (Lewis-Beck 1994). Because the number of factors are not hypothesized beforehand, all latent variables influence all observed variables, measurement errors are presumed to be uncorrelated, and often under identification of parameters in the model exists.

In contrast, CFA assumes that factor analysis is done based on an underlying theory. Therefore the factor analysis is conducted based on a theory which shows which indicators are suitable for the specific factor. For CFA the researcher should know the number of factors in the model beforehand. He can also predict which variables will load on which factors. In this way it is also possible to investigate whether measures created to represent a latent variable really belong together(Jae-On and Mueller 1978). As mentioned before the number and presumed effect of latent variables has been hypothesized beforehand. The measurement errors may correlate and parameters should be identified.

For each of the modules in the conceptual model there are several questions in the surveys that are relevant to be used. Using the literature review (theory) I conducted the factor analysis. Thus I have chosen Confirmatory Factor Analysis (CFA) as opposed to Exploratory Factor Analysis (EFA).

There are two extraction methods to conduct Confirmatory Factor Analysis (CFA). These approaches are called Principal Axis Factoring (PAF or Common Factor Analysis), and Principal Components Analysis (PCA). PAF is used to explain the common variance (correlations) of variables while PCA explains the variance between variables. The result of PAF is always factors while PCA produces components. PAF is commonly used to measure the latent variable and PCA is commonly used to summarize data. Because I wanted to have accurate measure of the latent variable rather than summarizing data I opted for PAF. In PAF the exclusion of unique variance leads to more accurate measurement.

After the choice of the method the following primary requirements should be satisfied:

- The variables included in FA should be interval or ratio.

- The sample size should be minimally five times as many as number of variables. In the panel dataset I have 56730 observations which is much larger than the minimum required number of 418*5= 2405.

Choice of appropriate factor

The number of the factors produced is equal to the number of the variables. To choose the most appropriate factor one there are three approaches:

1. surrogate variable where only one indicator is chosen top represent factor

2. factor score: where indicators are weighted by their factor loadings and so indicators with low loadings are also included

3. summated scale where summation of the scores of all high loading indicators are calculated. In this case each indicator has equal weight.

The last approach is more accurate compared to the other two and I opted for this approach.

One of the common criteria used for choice of factor is Kaiser Criterion (or K1 rule). This criterion is based on Eigen value. Eigen value is a number produced for every factor which represents the total variance a factor explains. Every variable contributes a variance of one to the total variance. In order to reduce data a factor should always explain more than the variance of a single indicator. Therefore the Eigen value should be more than one for the factor to be suitable. This is what Kaiser Rule indicates.

For each set of variables new set of factors can be created using rotation. In rotation sum of Eigen values will not change but the Eigen values themselves alter. In this way the factor loadings of certain factors are affected. Using rotation, factors generated will be more explainable. This is commonly used when more than one factor has an Eigen value of larger than one (rotation is not possible when only one factor with Eigen value of larger than one is produced). There are two choices for rotation Orthogonal and Non-Orthogonal (or Oblique). In orthogonal rotation the final factors produced are orthogonal and not dependent on each other while in oblique rotation, the final factors produced are dependent on each other. It has to be noted that if we use orthogonal rotation, then a further stage of factoring is not possible. This is because in the first stage, by using orthogonal rotation, the factors produced are independent and uncorrelated. Therefore grouping them together would be illogical and in fact impossible. In addition orthogonal rotation is appropriate for regression analysis on the factors generated while oblique rotation's results are closer to practice and reality.

Because I have used the second stage factor analysis to create a final factor for each module, I opted for Oblique rotation. The most common method for oblique is Varimax and the minimum threshold chosen for this method is 0.3.

Factor reliability

After distinguishing the most appropriate factor, the reliability of the factor is tested. There are three criterion used for this reliability check: *Bartlett's test of sphericity, KMO measure of sampling adequacy*. And Cronbach's alpha.

Bartlett's test of sphericity: this test compares the determinate of correlation matrix to that of identity matrix. If these two differ considerably then the factor is reliable.

KMO measure of sampling adequacy(Kaiser 1974): This criterion considers the correlation and partial correlation of variables to indicate whether these variables are likely to factor well or not.. In other words a factor should extract at least as much as the equivalent of one original variable. This criterion is the most widely used (Lewicki and Hill 2005). The following KMO index is used when considering this criterion for factor reliability.

KMO-value	*Degree of common variance*
0.90 to 1.00	Marvelous
0.80 to 0.89	Meritorious
0.70 to 0.79	Middling
0.60 to 0.69	Mediocre
0.50 to 0.59	Miserable
0.00 to 0.49	Do not use factor analysis.

Cronbach's alpha (Cronbach): This criterion measures how well a set of variables measures a single unidimensional latent construct. In case of a multidimensional structure of data, Cronbach's alpha will usually be low.

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

N is the number of observations, c bar is the average inter-item covariance among the items and v bar is the average variance.

Alpha ranges from 0 to 1. The closer alpha is to 1, more reliable is the factor. Although there is no specific number used as reference to good alpha, Nunnaly has introduced 0.7 to be suitable for factor construction in natural and applied science (Nunnaly 1978).

In short the criterions to be considered (after havening chose PAF method) are:

- Sufficient number of valid observations (limited number of missing)
- Eigen value >1, % variance explained by factor should be as large as possible
- KMO > 0.7 , Cronbach's Alpha > 0.7
- communalities>0.25 (this is driven from the communalities matrix and it shows the part of the variance an indicator shares with other variables or i.e. the variance the factor can explain

I will give a detailed example for the collaboration module. Detailed results for other factors are provided in the appendix.

Collaboration	variables	Description	Valid	Missing
internal	co_within_concern	collaboration with enterprises within enterprise group		33,605
external	co_client	collaboration with clients or customers	22,765	33,605
	co_supplier	collaboration with suppliers	22,765	33,605
	co_competitor	Collaboration with competitors	22,765	33,605
	co_private	collaboration with private institutes	22,765	33,605
	co_uni	collaboration with universities	22,765	33,605
	co_public	collaboration with public and semi-public institutes	21,254	33,605

From the questionnaire there were 7 variables that explained collaboration partners of a firm. They can be divided into internal and external. I used first stage factor analysis (method PAF) to construct the first factor. The Factor analysis output from SPSS for external collaboration is:

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.868
Bartlett's Test of Sphericity	Approx. Chi-Square	51,835.544
	df	15
	Sig.	0.000

Communalities

	Initial	Extraction
co_client	0.457	0.505
co_supplier	0.428	0.457
co_competitor	0.346	0.406
co_private	0.429	0.507
co_uni	0.518	0.556
co_public	0.547	0.611

Extraction Method: Principal Axis Factoring.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.528	58.803	58.803	3.042	50.700	50.700
2	0.687	11.452	70.255			
3	0.578	9.639	79.893			
4	0.488	8.134	88.027			
5	0.398	6.639	94.666			
6	0.320	5.334	100.000			

Extraction Method: Principal Axis Factoring.

Factor Matrix(a)

	Factor
	1
co_client	0.711
co_supplier	0.676
co_competitor	0.637
co_private	0.712
co_uni	0.746
co_public	0.781

Extraction Method: Principal Axis Factoring.
a. 1 factors extracted. 4 iterations required.

Factor Score Coefficient Matrix

	Factor
	1
co_client	0.203
co_supplier	0.174
co_competitor	0.146
co_private	0.197
co_uni	0.214
co_public	0.268

Extraction Method: Principal Axis Factoring.
Factor Scores Method: Regression.

Factor Score Covariance Matrix

Factor	1
1	0.864

Extraction Method: Principal Axis Factoring.
Factor Scores Method: Regression.

You can see that the KMO for external collaboration is 0.868 > 0.7. Eigen value is 3.528 which is much larger than one and explained 58.803 of the variance. For the reliability Cronbach's alpha is 0.866 >0.7. The second stage factor analysis is done in a similar way grouping the only variable for internal collaboration with the factor generated for external collaboration. The Cronbach's alpha is 0.64. This is considered reliable although it is not higher than 0.7 suggested by Nunnaly (Nunnaly 1978). Because 0.7 has been considered by Nunnaly reliable in natural and applied science, in management and social science alpha can be as low as 0.4 to be acceptable. This is because in this field it is very difficult to specify one specific threshold compared to natural and applied science.

		Cronbach's alpha- first stage FA	**Cronbach's alpha- second stage FA**
Collaboration	**variables**		**0.64**
internal	co_within_concern		
external	co_client	0.866	
	co_supplier		
	co_competitor		
	co_private		
	co_uni		
	co_public		

Factor analysis stages are shown on the conceptual model on the next page, Figure 8.

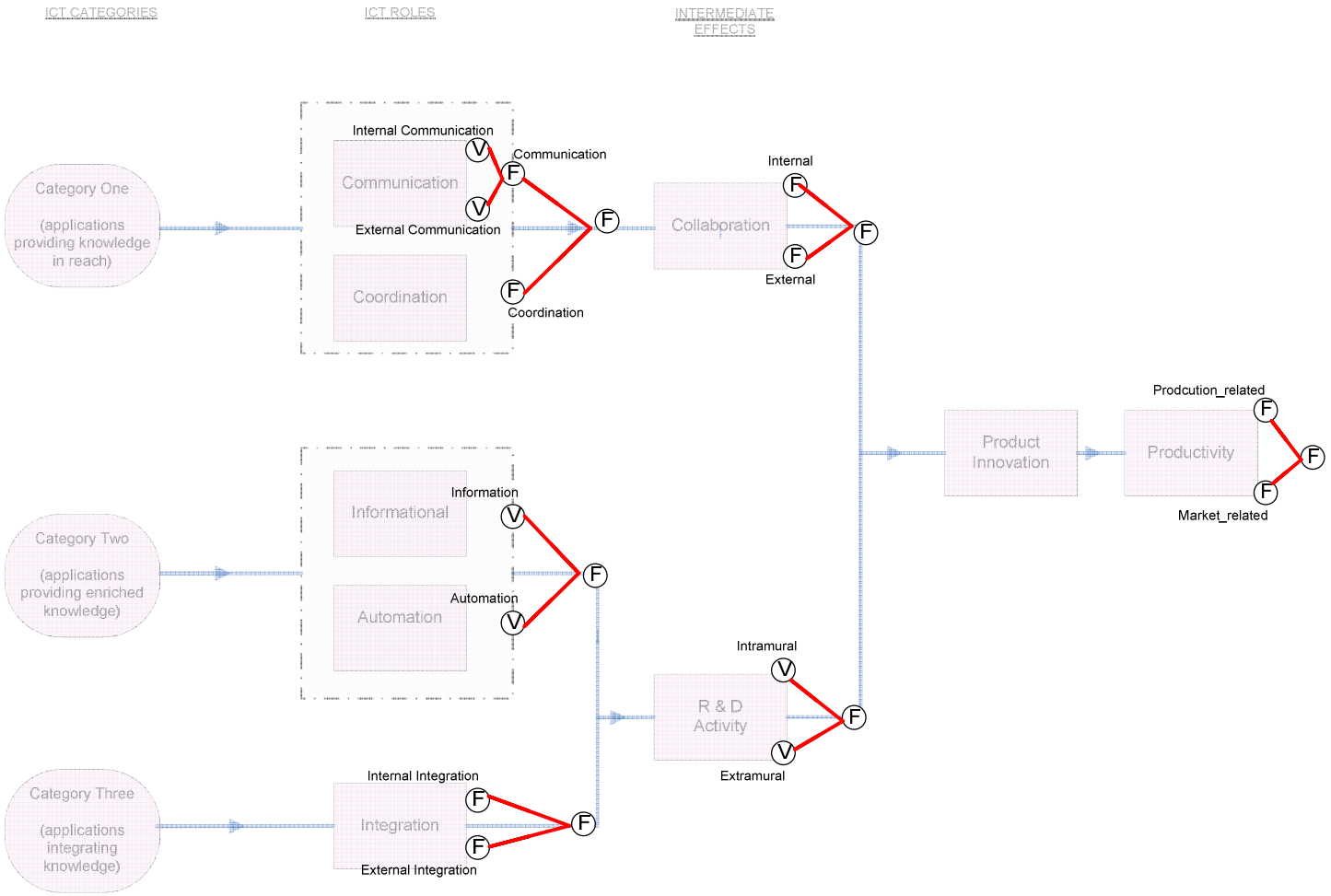


Figure 8: Factor analysis stages
"V" is one variable created from combination of several variables
"F" is one factor representing several variables

7 Chapter seven: Empirical Analysis results

Motivation: This chapter tests the hypotheses which were designed in the previous chapter. As mentioned in the previous chapter, H1 and H2 test the relation between ICT usage belonging to different categories of ICT (category one, category two, category three) and the intermediate variables. For each intermediate effect the relevant ICT category was further broken down to their composed ICT roles. Hypothesis H3, tests the contribution of intermediate effects on product innovation. H4 is tests the link between category one, collaboration and product innovation. H5 is designed to test the relation between ICT usages, thus contribution of ICT applications from all three categories to product innovation. Next set of hypotheses ranging from H6 to H8 are related to productivity. Product innovation contribution to productivity is tested in H6 and intermediate effects together with product innovation are involved in H7. Finally H8 tests the contribution of ICT usage and intermediate effects to productivity. This will give a general view about whether ICT enhances productivity.

First the descriptive statistics of al the variables used and their operationalization is provided.

7.1 Descriptive statistics

Table below provides the descriptive statistics for variables and factors used throughout the analysis.

ICT usage (roles)

Variable	Description	Observations	Mean	Standard Deviation
commu_fac_final	Factor - ICT applications used for communication role	18214	.0084567	.7628992
coord_ecommmerce_fac1	Factor representing ICT applications used for coordination role	7251	.1060908	.8675978
Commu_coord_fac_final	Factor - category one ICT (communication and coordination role)	7251	.030041	.6810449
aut_info_security_maintenance_va	Variable - ICT application used for information role	7839	.9198877	.2714842
integration_fac_final	Factor - ICT applications used for coordination role	6263	-.012345	.7623683
integration_internal_fac1	Factor representing ICT applications used for internal integration role	7839	.9198877	.2714842
integration_external_fac1	Factor - ICT applications used for external integration role	7794	-.001387	.8753985
ict_roles_factor_final	Factor - ICT applications of all roles/categories	6263	0.0246369	0.8946628

Intermediate effect

Variable	Description	Observations	Mean	Standard Deviation
collab_fac_final	Factor- collaboration	20177	-.0575594	.849413
rd_fac_final	Factor- R&D	28967	1.09e-08	.7722493
activity_intramural_rd	Variable- - intramural R&D	28936	638169.1	1.31e+07
activity_extramural_rd	Variable- - extramural R&D	28965	160628.1	2773051

Innovation

Variable	Description	Observations	Mean	Standard Deviation
innovation_novelty	Variable- - percentage of new product (turnover of new product divided by total turnover)	31885	.0837623	.1567622

Productivity

Variable	Description	Observations	Mean	Standard Deviation
productivity_fac_final	Factor – intangible effects	7689	7.22e-10	.6955893
prod_mrkt_related_effect_fac	Factor – intangible market related effects	7689	2.29e-09	.8738609
production_related_effect_fac	Factor – intangible production related effects	7689	-1.11e-09	.8423229
productivity_labour_deflated	Variable – Financial effect (Turnover divided by number of employees)	29407	570146.8	2.22e+07
productivity_labour_ps_0	Variable – Financial effect (Turnover divided by number of employees) for time lag 0	29397	207788.4	834955.6
productivity_labour_ps_p1	Variable – Financial effect (Turnover divided by number of employees) for time lag 1	20198	197904.9	544010.1
productivity_labour_ps_p2	Variable – Financial effect (Turnover divided by number of employees) for time lag 2	22481	210125.6	723381.9
productivity_labour_ps_p3	Variable – Financial effect (Turnover divided by number of employees) for time lag 3	15295	196467.9	679354.2

Interaction terms

Variable	Description	Observations	Mean	Standard Deviation

interaction_rd_integ_aut	Variable – R&D, integration role and automation role simultaneously	2268	.1577507	.6374265
interaction_collab_co	Variable – collaboration and communication, coordination role simultaneously	2647	.134582	.6413197

Sectors

Variable	Description	Observations	Mean	Standard Deviation
sector_service	Dummy Variable – service sector	56370	.5629413	.496027
sector_other	Dummy Variable – other sector (all sectors excluding service and manufacturing)	56370	.1365265	.3433499

Control Variables

Variable	Description	Observations	Mean	Standard Deviation
size	Variable – log of number of fte employees	56367	3.857568	1.370614
age	Variable – age of firm	48208	20.17082	11.60407

Number of observations is 56370. All the above variables are numerical except the sectors which are dummy variables. By looking at the number of observations for each variable/factor, we can see that the number of observations is quite large.

Sector distribution

Sector	Percentage
Industry_sector	30%
Service sector	56%
Other sectors	14%
TOTAL	**100%**

Sector division is shown in Figure 8 below.

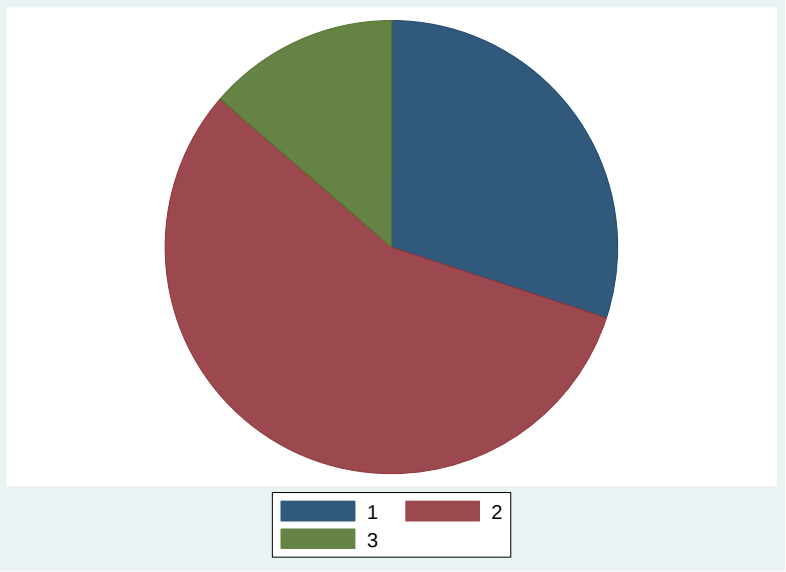


Figure 8: sector division
1: manufacturing 2: services 3: other

Sectors:

1. Manufacturing:

2. Services:
   reparation and trade of consumer product
   hotel and catering
   transport and communication
   financial institutions
   rent and trade of property and non property) goods
   public governing, government services and obligatory social insurance
   education
   healthcare and welfare
   environment, culture, recreation and other services
   private households with personnel in paid employment
   extra territorial bodies and organizations

3. other:
   Agriculture, hunting, sylviculture
   fishery
   extraction of minerals
   production, distribution and trade in electricity, natural gas, steam and water

Size variable

	Observations	Percentage
Number of employees < 500	28402	50%

Half of the observed firms are small firms.

The following graph (Figure 9) depicts the size (number of employees is shown rather than log of employees to enable us to see the difference better) and firm age.

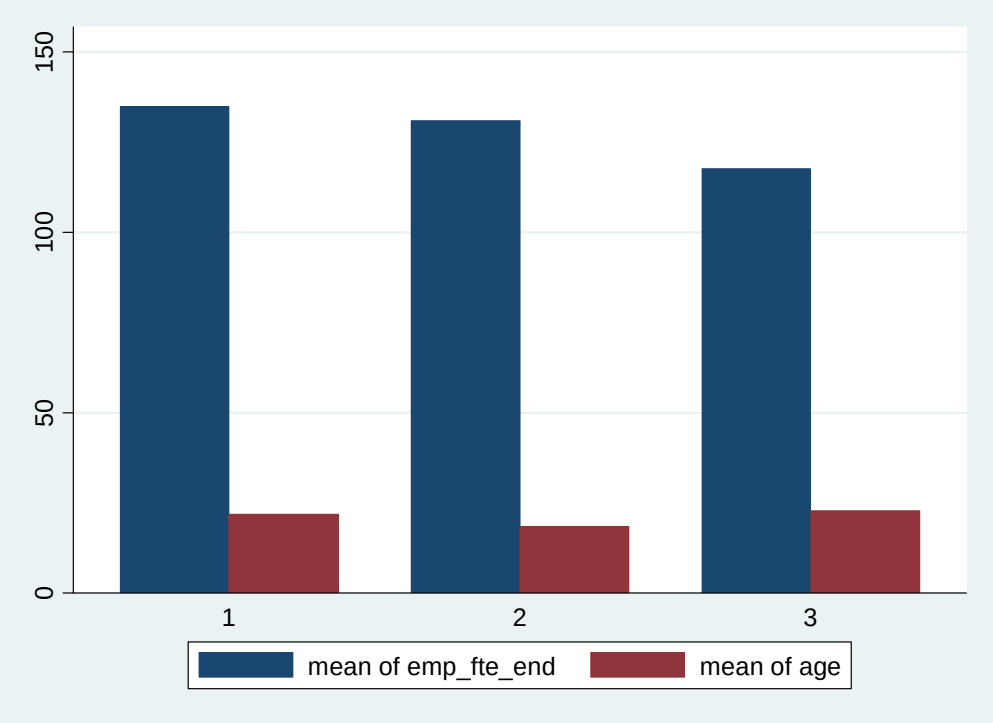


Figure 9: mean of number of employees and firm size per sector

Operationalization

- which variables to choose from survey for modules

Measuring ICT roles

As I mentioned in the previous chapter the CFA(confirmatory factor analysis) was chosen. One assumption to use this method is to have an underlying theory to group the variables together before conducting the factor analysis. For each ICT role I have extracted the relevant and common questions among the ICT questionnaires of years 1993-2005. Based on theory I have grouped them together and then performed the factor analysis. Below I will explain each role and the constructs used to explain them.

Communication and Coordination role: first and second order FA was used to construct this role.

Communication: Based on the definitions given in chapter three for communication role, the ICT applications that are used for communication belong to this category.
The extracted questions which were about an ICT application for communication are shown in the table below. They all are communication tools through which firms use to communicate. According to their usage (used internally or externally) they are divided into two main categories. Internal communication includes the ICT tools which are primarily used for internal communication. External communication include ICT tools which are used for external communication with other enterprises, suppliers or customers.

Internet is one of the variables used. Although internet has broad applications but it can be argued that major communication in firms is done through internet such as email, video conferencing.
According to the definition used in ICT questionnaire Internet relates to internet protocol based networks: www, extranet over internet, EDI over the internet, internet enabled mobile phones. Thus through the networks communication is done and EDI which is related to transaction is also done through internet. But I placed this variable in external communication because the primary indication of the question has been on communication. More specific and accurate indications of electronic transaction have been used by set of indicators which I have grouped under the title Ecommerce.

Variable from ICT survey	Description of what it indicates	Factor explained by question (1st stage)	ICT role explained by question	Second order Factor (2nd stage)
tcp/ip	Whether firm uses tcp/ip based network	Internal communication Factor	communication	Communication and coordination Factor
LAN	Whether firm LAN?		Communication	
NETW_OV	Whether firm uses non-TCP/IP networks		communication	

EXT_NETW	Whether firm uses external networks		communication	
EL_INKP	Whether electronic purchase from suppliers is possible	e-commerce Factor	coordination	
EL_VERKP	Whether receiving orders electronically from customers is possible		coordination	
EL_LEVER	Whether electronically delivery to customers is possible		coordination	
EL_SERV	Whether electronically after sale service to customers is possible		coordination	
ICT_SYST	Whether firm has and electronic order system		coordination	

Ecommerce All financial and informational electronically mediated exchanges between an organization and its external stakeholders. (Chaffey, Mayer et al. 2006)

Information and automation: only first order FA was used to construct this role. Information refers to first level processing, storage, and update which was mentioned before in chapter three. Several variables from the ICT questionnaires are related to security (internet, information access security such as encryption, identification system and digital signature) and several address data maintenance such as using update and back-up systems. These variables were all combined to form one variable representing all first order data processing. The reason I did not opt for factor analysis is that the extent to which a firm uses these variables as not my interest. In other words I was only interested in considering whether a firm uses either of these variables or not rather than being interested in knowing exactly which.

For second level data processing there was one variable which showed whether firm was automated or not. This indicator covers the second level processing which is done by ICT application in firm instead of people. Thus by automation, more than data storage, security and update is done.

Variable from ICT survey	Description of what it indicates	Variable explained by question	ICT role explained by question	Second order Factor (2nd stage)
BV_SERVR	Whether firm uses secured web server	Internet security and data maintenance variable	Informational	Information and Automation factor
BV_FWALL	Whether firm uses firewall		Informational	
BV_VIRUS	Whether firm uses anti-virus		Informational	

BV_UPD	Whether firm uses update		Informational	
BV_BACK	Whether firm uses off-site back-up		Informational	
BV_ENCR	Whether firm uses encryption		Informational	
BV_ID	Whether firm uses identification system		Informational	
BV_SIGN	Whether firm uses digital signature		Informational	
automat	Whether firm has been automated	Automation variable	Automation	

Integration role: This role is defined in chapter three and all ICT applications which connect several entities to unite them belong to this category. A set of variables are related to this role. By referring to value chain concept I have divided these two variables into internal and external integration. Internal integration only considers the firm itself and it includes all ICT applications which connect several units/departments of a firm in order to form one entity. By considering Porter's value chain, each of the indicators relate to one part of Porter's value chain.
External integration considers entities outside the firm and along the value chain. These include suppliers and buyers/customers.

Integration			
internal system integration	KOPP_VRD	storage administration system?	Integration
	KOPP_FAC	payment system	integration
	KOPP_PLN	production planning system	integration
	KOPP_LOG	logistics planning system	integration
	KOPP_MRK	marketing planning system	integration
external system integration	KOPP_KL	customers' business system	integration
	KOPP_TOE	suppliers' business system	integration
			integration

Measuring intermediate effects: collaboration and R&D

Collaboration: Two stage factor analysis is conducted. A set of variables from CIS questionnaire relate to firm's collaboration partners. Two kind of collaboration can be defined. One consists of collaboration with partners within same enterprise (within firm's own concern). This is the internal collaboration. On the other hand firms interact and further collaborate with suppliers, customers, competitors and public or semi-public institutions. These variables are considered as external collaboration.

Collab			
internal	co_within_concern	collaboration with enterprises within enterprise group	
external	co_client	collaboration with clients or customers	0.866
	co_supplier	collaboration with suppliers	
	co_competitor	collaboration competitors	
	co_private	collaboration with private institutes	
	co_uni	collaboration with universities	
	co_public	collaboration with public and semi-public institutes	

R&D
One stage factor analysis is conducted.

R&D	
	activity_intramural_rd
	activity_extramural_rd

Measuring Innovation
Innovation is defined in two measures of innovation novelty and innovation novelty. Innovation novelty measures the extent of new products and is define as:
Turnover from new product divided by total turnover

Measuring Productivity
Productivity is considered in two different ways. One is based on productivity statistics from PS questionnaires and the other is from intangible measures from CIS questionnaire.

The first measure is labor productivity which is obtained from dividing the total turnover to the number of employees. Total turnover is derived from the PS questionnaire but four issues were taken into consideration:

1. Employee statistics were available as fte (full time employee) and number. I opted for fte.

2. PS datasets which I linked together ranged from 1993 to 2004. The early years the financial statistics were all based on gilders while in the recent datasets these amounts were saved as Euros.

3. Because the PS surveys ranged from different time periods, I used price index deflators to calculate the real financial values. These price indexes were provided for each year and for each sector separately. Year 1990 was taken as reference and the price index for each year was produced compared to the previous year, so for example the price index of 1998=1.3 means that this 1.3 deflator is calculated based on the deflator of 1997. Price indices are provided on page 79.

4. These price indexes which were provided at CBS were limited to a number of sectors.

Except economic effects, intangible effects are also included to have more accurate results.

Regression model

According to different hypothesis we construct and run the appropriate regression model. The basic model followed is:

$y_{it} = \beta_{it} x_{it} + u_{it}$ + sector_service + sector_industry

where y is the dependent variable, β is the coefficient or predictor, x is independent variable, u is the error term, I refer to each firm and t represents the time period.
We start from the first hypothesis. Two dummy variables of sector_service and sector_industry which are dummy variables are added to the regression. Firms are divided into three sectors of manufacturing, service and others. Manufacturing sector is chosen as reference and thus not included in the regression (any of the other two sector dummies could have been chosen as reference).
In addition, suitable control variables supported by literature have been added to each regression.

For each regression Hausman test is conducted in order to decide on FE or RE estimator to use (previous chapter extensively discusses these two estimators).

Results

In all regression sector dummies are added in order to be able to compare the different sectors together. Because the main difference is between service and manufacturing sector, theses two are analyzed throughout the regression results. Adding these dummies improves each regression model as well.

H1: Category one ICT applications and collaboration
H1.1: Category one ICT applications are positively related to collaboration

Regression model:
collab_fac_final = β_0 + β_1 commu_coord_fac_final + β_2 size + β_3 age+ β_4 org_innov_relations + β_5 multination+ β_6 sector_service + β_7 sector_other

Control Variables
In order to improve the regression model, certain control variables are added. Control variables for each regression model depend on the dependent variable and are thus not similar in all the regressions. Relevant control variables are added according to literature, intuition and data availability.

Control variables for collaboration are: size, age, multination and org_innov_relations. Size is positively related to collaboration (Bishop 2003) . Larger firms have the tendency to collaborate more. Large firms have resources and facilities (such as in-house R&D), larger number of qualified personnel for collaboration and are better prepared to collaborate. So we expect a positive sign for β_2. Age however is expected to be negatively related to collaboration. Younger firms have the flexibility to collaborate extensively and in different fields of business. The risk they face collaborations is less than that of large firms. Therefore we expect β_3 to be negative. Org_innov_relations is a

variable which indicates whether there have been new or significant changes in the relations of firm with other firms or public institutions such as through alliances, partnerships, outsourcing or sub-contracting. If there is a change in firms' relations, then its collaboration is affected. A positive sign is predicted for β_4. The last control variable for collaboration is multination. This variable shows whether firm a multinational company is or not. Multinational firms have access to new markets and opportunities and are stated in global competition. Therefore they collaborate more and β_5 is expected to be positive.

Collab_fac_final	
commu_coord_fac_final	0.105 (1.76)
size	0.239*** (10.42)
age	- 0.00525* (-2.25)
org_innov_relations	0.279*** (4.25)
multination	0.159* (2.39)
sector_service	-0.330*** (-5.13)
sector_other	-0.102 (-0.87)
_cons	-0.533*** (-4.38)
N	1610
R-square	0.1241

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

As we can see from the regression table, commu_coord_fac_final is positively related to collaboration. The coefficient is 0.105 and positive. However it is not significant. Communication and coordination together contribute positively to collaboration. Communication and coordination include ICT applications which enhance these two roles. Internal and external networks enable individuals and also different firm units to communicate. Communication through these networks has been extended as well as enhanced (through speed and reliability). Individuals from different departments within

the firm and also external to the firm communicate more easily. Communication is the basic enabler of collaboration but is not the only factor needed. Coordination between the partners collaboration is essential as well. Electronically available systems constructed the coordination role in our data base. Existence of these variables in a firm results in coordination.

Sector wise we can see fro the table that the result only for service sector is significant. This means that the service sector is significantly different from the base sector which was the manufacturing sector. Collaboration is more common in manufacturing sector regarding product innovation. Process of new product development includes many stages starting from idea generation, to design and production. Firms can collaborate in each of theses phases. Collaboration with customers occurs in stages before idea generation while collaboration with suppliers occurs while the product is ready to be produced and later delivered. Compared to the service sector, where new service (as product) does not usually involve the aforementioned phases and thus requires relatively less collaboration. I have to note that service sector includes industries such as transport, catering, education, etc (see descriptive statistics). For example in the transport sector, a new service may be developed through close collaboration with suppliers. You can see that there not different phases compared to product innovation in manufacturing sector. In short, manufacturing sector seems to be the most collaborative compared to the other two sectors.

The result for the sign of the control variables were as expected. We can see that the result for size and org_innov_relations are highly significant. Therefore these two variables are strongly related to collaboration. With increase in size firms do have the tendency to collaborate more. This may be due to their readiness for collaboration. As mentioned before, larger firms have qualified and sufficient number of employees as well as resources needed for collaboration. Org_innov_relations shows whether there has been a change in firm's partnerships or not and obviously this is strongly related with whether the firm collaborates or not.

R squared shows the relative predictive power of a model which is a descriptive measure between 0 and 1. The closer it is to one, the better your model is i.e. it has greater ability to predict. But the value of R squared is usually very low for panel datasets where researchers are satisfied will R-square as low as 0.1. It depends where the "noise" in dataset is and so a result with a "poor" R-squared may in fact contain much more information than, in another science, a result with an R-squared near one3. In addition when comparing a dependent variable of one firm at different times we can explain much of the variation with a few variables while we are comparing the same variable for different firms, the same few variables will be explaining less. Therefore R-square for panel data is extremely low, as we will see on other regressions as well.

H1 .1 cannot be rejected and therefore:
Category one ICT applications are positively related to collaboration

[3] For more information see http://www.stata.com/statalist/archive/2003-05/msg00336.html.

H1.2: Communication role and coordination role (roles of ICT applications from category one) are positively related to collaboration

Regression model:

collab_fac_final = β_{0+} β_1 commu_fac_final + β_2 coord_ecommmerce_fac1 + β_3 size + β_4 age+ β_5 org_innov_relations+ β_6 multination+ β_7 sector_service + β_8 sector_other

Control Variables

Control variables used are the same as the ones used for the previous regression, because both regression models have the same dependent variable (collaboration). Obviously the signs expected for each control variable are also the same as before.

collab_fac_final	
commu_fac_final	0.0856 (1.02)
coord_ecommmerce_fac1	0.0479 (1.36)
size	0.239*** (10.35)
age	-0.00525* (-2.25)
org_innov_relations	0.279*** (4.25)
multination	0.159* (2.39)
sector_service	-0.328*** (-5.06)
sector_other	-0.100 (-0.85)
_cons	-0.543*** (-4.50)
N	1610
R-square	0.1241

t statistics in parentheses

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

The result from the table shows that ICT applications with communication role and ICT applications with coordination role each have positive impact on collaboration. This means that with the increase in ICT usage of either role, collaboration increases.

With more careful look at the table we realize that the coefficient related to communication role is as twice as large as the one attributed to coordination role. This means that communication has a larger effect on collaboration (assuming everything else being equal) than coordination role. This is explainable. Coordination is a sub result of communication. In other words coordination is a consequent of communication. When individuals communicate, coordination is formed among them. ICT tools used to create coordination for example electronic systems for customers, provide the coordination between customer and the firm through an indirect communication. I used "indirect" because communication was defined as two way interaction whereas coordination here results from a one way interaction of customer and firm (as example).

In short, coordination results from communication and cannot be provided without communication. So among ICT tools used for communication there are tools which enhance coordination. But because these tools are only one part of communication role tools, their related role (coordination) seems to be less effective for collaboration.

Sector wise, we have more or less the same result as before. Service sector is not as collaborative as the manufacturing sector. It is significantly different from manufacturing. Beside the reasons given in the previous regression result I will add another reason here. Innovation is the center theme of any business today, be it in the manufacturing sector or service sector; in other words achieving competitive advantage by means of innovation. Service sector firms are not an exception and they thrive to be innovative. They have changed the traditional view where banks and financial institutions were thought not to be able to innovate. In an analysis of CIS3 (innovation survey of year 2000-2002) it is conclude that service firms do not collaborate to innovate. Although larger firms in the service sector were more likely to collaborate, but still the level of collaboration was lower than that of the manufacturing sector. In short, service sector don't seem to collaborate as much as manufacturing sector.

H1 .2 cannot be rejected and therefore:
Communication role and coordination role (roles of ICT applications from category one) are positively related to collaboration

H2: Category two and three ICT usage are positively related to R&D

Regression Model

rd_fac_final = β_0 + β_1 aut_info_security_maintenance_va + β_2 integration_fac_final + β_3 rd_personnel_fte + β_4 type_firm + β_5 sector_service+ β_6 sector_other

Control variables

For improving the regression model, control variables regarding rd_fac_final (Research and development activities) have been added. These variables are rd_personnel_fte and type_firm. The first one indicates the number of the R&D personnel a firm has (as fte or full time employment). The larger the number of R&D personnel, larger number of

people will be engaged in R&D activities and thus R&D activity of the firm increases. Therefore the sign for β_3 is predicted positive.

The second control variable is type_firm which indicated whether firm is solely an R&D institute or not. Obviously if the firm is an R&D institution it is predicted to have higher R&D activities (because this will be its major role) than other firms. β_4 are also predicted to be a positive number.

rd_fac_final	
aut_info_security_maintenance_va	0.210* (1.97)
integration_fac_final	0.0465* (2.04)
rd_personnel_fte	0.000682*** (5.00)
type_firm	0.257*** (6.86)
sector_industry	0.128*** (3.62)
sector_other	0.205** (3.07)
_cons	0.127 (1.16)
N	1360
R-square	0.0939

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

The result from the table show that ICT usage having automation role and ICT usage having integration role each have positive contribution to R&D activity of the firm. This result is aligned with the prediction according to the literature review in chapter four. If the firm does its first and second level processes through ICT application; (i.e. if the firm is automated) R&D activities will be done faster and will of higher quality. Because for example simulation applications provide a 3 dimensional environment (more appropriate for product development) and provide a more specific view of product being developed. This of course is a huge enhancement in speed as well as quality of product development.

We defined innovation as combination of set of knowledge. This definition is particularly important for product innovation. When developing a product you need many sets of data to be combined (e.g. information from customers demand, number of customers,

availability of suppliers, available technologies, etc). Certain ICT applications have the role to integrate various sets of knowledge across different entities. This of course enhances the process of product development in R&D department. The more ICT applications with integration role used the more R&D activity the firm will be engaged in.

There is a substantial difference in the coefficients of the ICT applications regarding each role. ICT applications of category two (from model) which have the automation role, influence R&D activity with a coefficient of 0.2 while ICT application from category three having integration role have a coefficient of 0.04 on R&D activity. This difference can be attributed to the frequency of usage of each role. All the activities of a firm are either first level process or second level process. In almost all the activities of a firm ICT application are used. Number of first level processes (simple processes such as transfer of data or security related activities) is not only more frequently used but also they are the base for second level processes. In other word second level processes can not be done without the existence of first level processes. This is why the coefficient for different ICT applications differs significantly.

Sector wise, the coefficient for manufacturing sector is positive and significant. This means that manufacturing sector's engagement in R&D activities significantly differs from service sector. The positive sign shows that R&D activity in manufacturing sector is much higher than that of the service sector.

The results are positive and significant. H2 cannot be rejected. Therefore *Category two and three ICT usage is positively related to R&D.*

H2 cannot be rejected and therefore:
Category two and three ICT usage are positively related to R&D

H3: Intermediate effects contribute positively to product innovation

Regression model

innovation_novelty = β_0 + β_1 collab_fac_final+ β_2 rd_fac_final + β_3 size + β_4 age + β_5 group+ β_6 process_innov+ β_7 org_innov+ β_8 total_innov_expend+ β_9 sector_other + β_{10} sector_service

Control Variables

Our dependent variable is innovation_novelty which is a dimension of product innovation. The relevant control variables included in the regression model for this dependent variable are size, age, group, process_innov, org_innov and total_innov_expend.

Although larger firms may seem to be more innovative in first glance, but smaller innovative firms are known to be more productive (Acs and Audretsch, 1998) in (Beers and Zand 2008). Therefore β_3 is expected to be negative. Older firms have been in a long learning process and are expected to be more innovative. Therefore β_4 is expected to be positive. Group variable shows whether firm a member of a group is or not. If a

firm is a member of a group then it faces more opportunities (in terms of having access to resources or availability of suitable partners). Thus it is predicted to be more innovative. Therefore β_5 is also expected to be positive. As explained before (in the product innovation definition) process and organization innovations may lead to product innovation. Positive sign are predicted for β_6 and β_7. The last control variable added to the regression is total_innov_expend. This variable shows the total innovation expenditure of the firm. The more investment a firm has in innovation, the more innovative it can be. Thus β_8 is predicted to be positive.

innovation_novelty	
collab_fac_final	0.00795*** (4.49)
rd_fac_final	0.00933** (3.05)
size	-0.0122*** (-4.90)
age	-0.00139*** (-6.18)
group	0.00643 (1.24)
process_innov	0.00385 (0.93)
org_innov	0.0489*** (11.56)
total_innov_expend	9.15e-10 (1.90)
sector_other	-0.0584*** (-3.99)
sector_service	-0.0240*** (-3.52)
_cons	0.204*** (13.85)
N	2308
R-square	0 .01804597

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

The table shows positive and highly significant results for both collaboration and R&D with regard to their contribution to product innovation. According to the literature these intermediate effects are the most important ones for innovation. Collaboration is conducted in every stage of product development. Firms collaborate with customers, suppliers and even their competitors. Collaboration brings firms closer to their partners and consequently results in increase in quality or leads to a new but demanding product. For example by collaborating with customers, firm becomes closer to customer's expectations.

R&D activities may include the whole process of product development except production. R&D department uses all kind of information (from customers, suppliers, market, competitors and even other departments of the firm) and conducts tests and simulations which all result in innovation (improve in quality or completely new product).

By comparing the coefficients of collaboration and R&D we realize that collaboration has more influence on innovation. Therefore increase in collaboration (everything else being equal) increases product innovation much more than R&D activities do. I have to note that the result for collaboration is more significant which adds to the strength of its contribution to product innovation.

Sector wise, we can see that service sector is significantly lower in product innovation compared to the manufacturing sector. This is because although according to statistical evidence service sector is innovative (unlike a few decades ago) it is not ahead of the manufacturing sector except in. Statistical evidence has shown that in few and limited areas service sector is more innovative than manufacturing sector (Sheehan 2006). In the table we can see that the level of significance for the service sector is extremely high so in our case service sector is much less innovative compared to manufacturing.

H3 cannot be rejected therefore:
Intermediate effects contribute positively to product innovation

H4: category one ICT usage and collaboration contribute positively to product innovation

Regression Model

innovation_novelty = β_0 + β_1 collab_fac_final + β_2 commu_coord_fac_final + β_3 size + β_4 age + β_5 group + β_6 process_innov + β_7 org_innov + β_8 total_innov_expend + β_9 sector_service + β_{10} sector_other

Control variables

The dependent variable in this regression is innovation_novelty which is the same as the one in the previous regression. Therefore the control variables used in this regression are also the same as the ones used in the previous regression. The expected results are also the same as before.

Innovation_novelty

collab_fac_final	0.0172*** (9.64)
commu_coord_fac_final	0.0567*** (13.26)
size	-0.0376*** (-19.64)
age	-0.000336** (-2.71)
group	-0.00394 (-0.65)
process_innov	0.0129*** (3.66)
org_innov	0.0372*** (11.65)
total_innov_expend	1.12e-09*** (46.95)
sector_service	0.0333*** (7.14)
sector_other	-0.0497*** (-3.68)
_cons	0.326*** (29.93)
N	462
R-square	0.04445342

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

The result from the table show positive and significant results for contribution of collaboration and category one ICT usage (communication and coordination) to product innovation. Collaboration as discussed before was expected to have the positive contribution to innovation. ICT applications attributed to communication and coordination role provide tools that enhance innovation. In order to develop or improve a product, coordination and communication is needed across several entities. The result confirms our assumption because the coefficient for this role is positive and highly significant.

What is interesting in this table is that communication-coordination which represents ICT application usage from category one, is much more influential for product innovation than the collaboration. This shows that using ICT tools which enable or

enhance communication and coordination is very important for product innovation. Although theses tools are used to enhance collaboration which in turn enhances product innovation, but the ICT tools of category one alone contribute much more than collaboration. We can conclude that the ICT tools enhancing communication and coordination role of ICT are not limited to collaboration enhancement. Therefore they probably influence R&D or other possible intermediate modules (not existing in the introduced model). This is stated in the future recommendations.

Sector wise, service sector seems to be much more innovative than manufacturing sector. This result is contradictory to the previous regression and what we expect. Service sector is known to be less innovative than the manufacturing sector (with exceptions in a few areas). Therefore a negative sign was expected for the coefficient of service sector. Also the "group" control variable was expected to have a positive sign. We can see from the table that the coefficient for "group" is negative. This may happen if any of these variables is highly correlated with another variable in the regression. Therefore I conducted a test to see the correlation between the variable in the regression. Table below shows the result. We can see that the service _sector has low correlation (less than 0.6) with the other variables. The same holds for "group" variable. There is one other possibility for the unexpected signs.

Among the control variables, group has negative sign which was not expected. Also service sector is unexpectedly showing positive coefficient. This may happen because of strong correlation that either of these variables have with other variables in the regression. Table 8 shows the correlation matrix for the abpve regression. As you can see there is nor strong correlation between either of factors (strong correlation is defined as correlation =>0.6).

If we look at the number of observations of the regression we can see that there are only 462 firms involved in this regression. Total numbers of firms are about 57,000 from which 18,000 are involved in product innovation. Having a sample of 462 is very small indeed. If this sample is not a very good representative of all firms involved in product innovation, then the unexpected result is explainable. In order to find out, I compared the mean (descriptive statistic) of the variables which were included in regression to the mean of the variables in general. Table 9 on the next page shows the result. The first table represents all the firms which have product innovation and the second table is our representative sample (observations which were included in the regression). If we compare the Mean of each variable in two different tables, we can see that all variables in the second table have almost the same mean as the variables in the first table. Collaboration variable is an exception. Mean of collaboration is -0.02 among firms while the mean for collaboration for firms included in the regression is 0.55. Therefore the sample is not a good representative.

The reason that the number of observations in the regression is so low is because of the command used to regress. This regression model was a fixed effect model. Wherever I was supposed to use a fixed effect model, in order to prevent heteroskedasticity and autocorrelation, I used the xtgls command. This command uses feasible generalized least squares. This command allows estimation in the presence of AR(1) autocorrelation within panels and cross-sectional correlation and heteroskedasticity across panels. There are two options to be used after this command panels(pdist) specifies the error

structure across panels and corr(corr) specifies the assumed autocorrelation within panels. These options should be specified after the xtgls command and are in fact obligatory rather than options! In each of these options for example in panels() you allow a certain kind of heteroskedasticity and prevent it in other cases. The same holds for corr() option. You allow a certain autocorrelation but the rest are prevented. These two options reduce the number of the observations substantially. In order to avoid heteroskedasticity and autocorrelation in panel data xtgls is the best choice. There is no test that remedies or prevents autocorrelation and heteroskedasticity when the simultaneously exist in panel data. This can be done by extensive programming which is extremely time-consuming and out of the scope of this paper. Therefore in order to take heteroskedasticity and autocorrelation into account I have opted to use xtgls instead of ignoring these two important issues with regard to panel data.

In short, the result of the table can be taken into account because it has already been dealt with heteroskedasticity and autocorrelation but on the other hand number of observations is reduced substantially to a sample which is not completely representative of all the observations. For now I conclude cautiously that communication_coordination and collaboration contribute positively to product innovation but further investigation should be conducted on the two variables that have unexpected result.

	innova~y	collab~l	commu_..	size	age	group	proces~v	org_in~v	t~inno~d	sector~e	sector~r
innovation~y	1.0000										
collab_fac~l	0.0457	1.0000									
commu_coor~l	0.0781	0.0516	1.0000								
size	-0.1333	0.3046	0.1369	1.0000							
age	-0.0920	-0.0351	-0.0457	0.0201	1.0000						
group	-0.0041	0.3021	0.0654	0.2159	0.0244	1.0000					
process_in~v	-0.0081	0.1903	0.0116	0.2115	0.0757	0.0458	1.0000				
org_innov	0.0550	0.1704	0.0778	0.1586	-0.0704	0.0635	0.1957	1.0000			
total_inno~d	0.0471	0.0966	0.0098	0.1452	0.0002	0.0301	0.0416	0.0383	1.0000		
sector_service	0.0609	-0.1104	0.1754	-0.1130	-0.2410	-0.0710	-0.1368	0.0584	-0.0465	1.0000	
sector_other	-0.0751	-0.0402	-0.1000	0.0863	0.0797	-0.0078	-0.0275	-0.0202	-0.0133	-0.1701	1.0000

Table 8: correlation matrix

Variable	Obs	Mean	Std. Dev.	Min	Max
innovation~y	14533	.1837721	.1885133	0	1
collab_fac~l	16116	-.0228144	.886889	-.4539622	2.804294
commu_coor~l	1911	.3112652	.4906213	-2.152706	1.11539
size	18799	4.24314	1.40876	-.6931472	11.39475
age	15691	19.86852	11.52954	1	38
group	18614	.6554744	.4752261	0	1
process_in~v	16108	.6112491	.4874817	0	1
org_innov	16606	.845598	.3613446	0	1
total_inno~d	5673	379712.7	5373210	0	3.05e+08
sector_service	18800	.4928191	.4999617	0	1
sector_other	18800	.0793085	.2702269	0	1

Variable	Obs	Mean	Std. Dev.	Min	Max
innovation~y	1304	.163622	.1981825	0	1
collab_fac~l	1304	.5571029	1.194083	-.4539622	2.804294
commu_coor~l	1304	.3393152	.4541446	-2.152706	1.11539
size	1304	5.100907	1.121632	2.468479	10.39622
age	1304	22.79294	12.3714	3	38
group	1304	.797546	.4019829	0	1
process_in~v	1304	.6273006	.4837086	0	1
org_innov	1304	.6763804	.4680363	0	1
total_inno~d	1304	656194.1	1.02e+07	0	3.05e+08
sector_service	1304	.375	.4843087	0	1
sector_other	1304	.0460123	.2095921	0	1

Table 9: descriptive statistics for regression of H4.

H4 cannot be rejected therefore:
category one ICT usage and collaboration contribute positively to product innovation

PRODUCTIVITY:
The most common used production function is the Cobb-Douglas production function. The underlying equation has the general form of:

$$Y = F(K,L) = A\, K^{a}\, K_{IT}^{c}\, L^{b}$$

Where:

Y = Output
K = non-IT Capital Stock
K_{IT}^{c} = IT capital stock
L = Labor (fte)
A = Technology
F denotes a function
a and b are positive parameters

Data on capital stocks were not available in the panel data. Therefore K can not be taken into account. Initially investment could be considered as an alternative. But there are major differences between capital stock and investment. Investment is change in capital stock and thus unlike capital is not measured at one instance of time. The variance for investment can vary significantly for different time periods and thus not reliable to be used as an alternative for capital stock. As an example, in the 90s investment grew 40% compared to 1980s while capital stocks declined 1.1% compared to 1980s. This was because the increasing share of investment in the 90 was due to ICT investment. But ICT equipments devaluate quickly and capital stock which is the total capital of equipment in a year declined (Edite Cruz thesis, TU Delft, 2007).
Beside the fact that investment is not a suitable measure for capital, the investment figures for ICT were available for a few years and were not available in the longitudinal data.

For hypotheses H6 and H7 productivity which is the dependent variable is measured by intangible effects. For each regression model in these two hypotheses three measures of productivity is used. The first measure is a factor *(prod_mrkt_related_effect_fac)* representing all the intangible effects. Then productivity is broken down into two different effect market related (prod_mrkt_related) and production related *(production_related_effect_fac)* effects.

H5: Product innovation and productivity
In order to test this hypothesis first productivity which is a factor measuring the intangible effect of performance is used. It includes market and production related effects which in turn will be used as well. Therefore for this hypothesis three separate regressions will be run: one for productivity (general intangible effect) , one for production effects and one for product_market effects. The result of regression will be shown in one table.

H5.1: Product innovation contributes positively to productivity(intangible effects)
Regression Model

productivity_fac_final = β_0 + β_1 innovation_novelty + β_2 size + β_3 age + β_4 multination + β_5 activity_acquire_machinery+ β_6 activity_training + β_7 market_innov + β_8 activity_market_intro + β_9 sector_service + β_{10} sector_other

Control Variables

The dependent variable in this regression is productivity_fac_final which represents the intangible effects or the intangible changes of firm performance. Control variables regarding this variable are size, age, multination, activity_acquire_machinery, activity_training market_innov and activity_market_intro.

Size is the first control variable I will discuss. Larger firms are more productive than small firms (Grossmann 2007). Large firms are more profitable but less productive (Majumdar 2004). Larger firms often have access to unique resources and thus can perform more efficiently. In addition large firms have to be more careful about their business approach because they often involve larger risks compared to smaller firms. β_2 is thus predicted to be positive. Contribution of age to productivity is predicted to be negative. Studies show that older firms are less productive than young firms .So β_3 is predicted to have a positive sign. Multination variable indicates whether firm is a multinational enterprise or not. Studies show that multinational firms are more productive than domestic ones (Karpaty 2004) (Meschi 2006). β_4 is thus expected to be a positive coefficient. Activity_acquire_machinery indicated whether new machinery was acquired by firm or not. Replacement of labor by machinery is predicted to have a positive effect on productivity. β_5 is thus expected to be positive. If a firm trains its employees, their knowledge and skills are updated and suitable and this is thought to increase productivity. So β_6 should be having a positive sign. If a firm is involved in market innovation i.e. if it explores new markets or is active in extending its market, its productivity should be increased. This is why β_7 and β_8 are expected to be positive.

H5.2: Product innovation contributes positively to productivity(production related effects)

Regression Model

production_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 size + β_3 age + β_4 multination + β_5 activity_acquire_machinery+ β_6 activity_training + β_7 sector_service + β_8 sector_other

Control Variables

The control variables size, age, multination, activity_acquire_machinery and activity_training have been explained before and their coefficients are expected to have positive signs except age.

H5.3: Product innovation contributes positively to productivity (product & market related effects)

Regression Model

prod_mrkt_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 size + β_3 age + β_4 multination + β_5 market_innov + β_6 activity_ market_intro + β_7 sector_service + β_8 sector_other

Control Variables
The control variables size, age, multination, activity_acquire_machinery and activity_training have been explained before and their coefficients are expected to have positive signs except age.

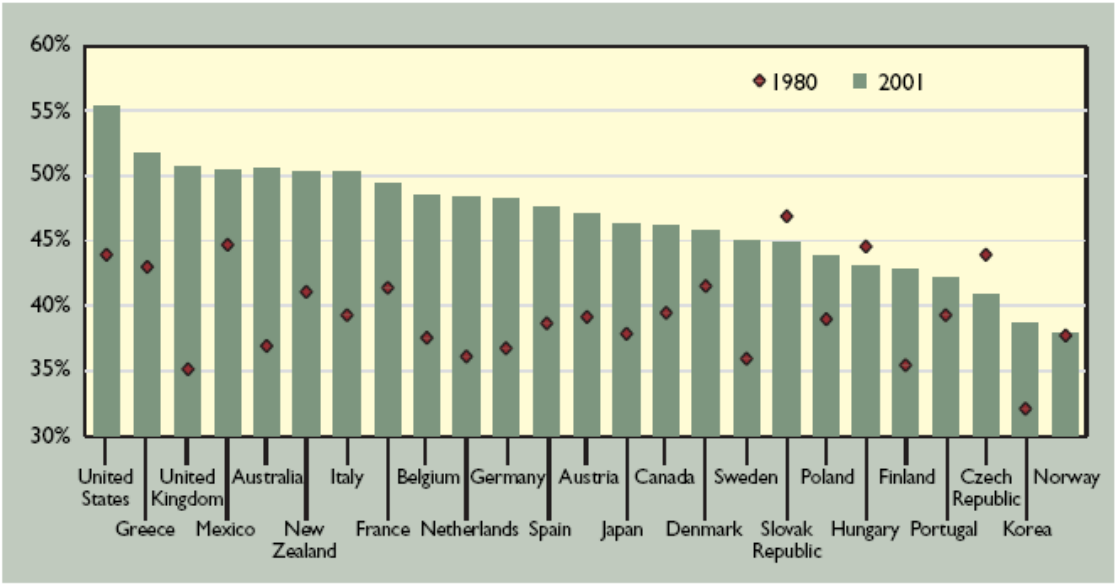
Productivity_fac_final		production_related_effect_fac		prod_mrkt_related_effect_fac	
Innovation_novelty	0.526*** (5.54)	Innovation_novelty	0.400*** (3.34)	Innovation_novelty	0.716*** (6.31)
size	0.0164* (2.09)	size	0.0329*** (3.32)	size	0.00470 (0.49)
age	-0.000957 (-1.14)	age	-0.00103 (-0.94)	age	-0.000941 (-0.94)
multination	0.0236 (1.00)	multination	-0.00500 (-0.16)	multination	0.0492 (1.79)
activity_acquire_machinery	0.236*** (10.91)	activity_acquire_machinery	0.381*** (13.57)	market_innov	0.144*** (5.92)
activity_training	0.139*** (5.24)	activity_training	0.138*** (4.94)	activity_market_intro	0.272*** (11.30)
market_innov	0.155*** (7.40)	activity_training	-0.298*** (-10.12)	sector_service	-0.128*** (-4.82)
activity_market_intro	0.0306 (1.17)	sector_service	-0.214*** (-4.14)	sector_other	-0.198*** (-4.01)
sector_service	-0.214*** (-9.48)	sector_other	-0.290*** (-4.79)	_cons	-0.0119 (-0.21)
sector_other	-0.192*** (-4.55)	_cons			
_cons	-0.182*** (-3.79)				
N	3587				

R-square	0.1339		0.1173		0.0793

Table results show positive result for innovation's contribution to productivity. All three results are highly significant. This means that product innovation has a positive and strong effect on intangible measures of productivity. The first regression indicates the general result. In other words it shows that with an increase in product innovation (other variables being equal), productivity (intangible effect) of firm increases. Therefore in order to increase productivity, firm can increase its product innovation. It can improve the existing products or develop new products. According to the definition of innovation novelty variable, new products are the ones that are new to firm or new to market. Therefore even if new products are only new to firm, they increase productivity.

To have a more detailed analysis, two other regressions provide more detailed results. We can see that although innovation's contribution is highly significant for production_related_effect_fac and prod_mrkt_related_effect_fac, contribution to the latter is considerably higher. This means that product innovation contributes more to product and market effects rather than production related effects. Product & market related effects include improvement in quality of new product, increase in range of product and entrance to new market. Production related effects relate to increase in flexibility, capacity & decrease in material usage. So with development of new products, firms increase product quality & range and their market territories.

Sector wise, we can see that service sector has a negative coefficient. This result is significant in all three regressions and we can conclude that productivity in service sector is significantly different from that of manufacturing. Productivity on service sector is much less than manufacturing. There is evidence from CIS3 about this difference. According to a study based on CIS3 market based services in Netherlands account for more than 45% of total value added in 2001 (Sheehan, 2006). Although this is a huge, it is not the majority of share. In addition, many manufacturing firms have linked their products to services by providing clients with product-services packages and integrated solutions (Sheehan, 2006). So their share is also included in the 45%. See Figure 10.



Source: OECD, *STI Scoreboard 2003*.

Figure 10: Share of market services in Total value, 1980 and 2001

According to the results neither of H5.1, H5.2 and H5.3 can be rejected. Therefore:

Product innovation contributes positively to productivity y(intangible effects

Product innovation contributes positively to productivity (production related effects)

Product innovation contributes positively to productivity (product & market related effects)

H6: Product innovation ,intermediate effects and productivity

H6.1: Product innovation and collaboration contributes positively to productivity

H6.1.1: Product innovation, collaboration contribute positively to productivity (intangible effects)

Regression Model

productivity_fac_final = β_0 + β_1 innovation_novelty + β_2 collab_fac_final + β_3 size + β_4 age + β_5 multination + β_6 activity_acquire_machinery + $\beta_7$acti vity_training + β_8 activity_market_intro + β_9 market_innov + β_{10} sector_service + β_{11} sector_other

H6.1.2: Product innovation, collaboration contribute positively to productivity (production effects)

Regression Model

production_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 collab_fac_final + β_3 size + β_4 age + β_5 multination + β_6 activity_acquire_machinery + $\beta_7$acti vity_training + β_8 sector_service + β_9 sector_other

H6.1.3: Product innovation, collaboration contribute positively to productivity (product & market effects)

Regression Model

prod_mrkt_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 collab_fac_final + β_3 size + β_4 age + β_5 multination + β_6 activity_market_intro + β_7 market_innov + β_8 sector_service + β_9 sector_other

Productivity_fac_final		production_related_effect_fac		prod_mrkt_related_effect_fac	
innovation_novelty	0.516*** (5.46)	innovation_novelty	0.389** (3.26)	innovation_novelty	0.704*** (6.21)
collab_fac_final	0.0491*** (4.91)	collab_fac_final	0.0539*** (4.05)	collab_fac_final	0.0512*** (4.57)
size	0.00737 (0.91)	size	0.0238* (2.33)	size	-0.00574 (-0.58)
age	-0.000776 (-0.92)	age	-0.000826 (-0.76)	age	-0.000733 (-0.73)
multination	0.0146 (0.62)	multination	-0.0153 (-0.50)	multination	0.0402 (1.46)
activity_acquire_machinery	0.224*** (10.25)	activity_acquire_machinery	0.366*** (12.93)	market_innov	0.142*** (5.85)
activity_training	0.131*** (4.92)	activity_training	0.124*** (4.41)	activity_market_intro	0.256*** (10.49)
market_innov	0.153*** (7.32)	sector_service	-0.292*** (-9.93)	sector_service	-0.120*** (-4.52)
activity_market_intro	0.0243 (0.92)	sector_other	-0.207*** (-4.01)	sector_other	-0.199*** (-4.04)
sector_service	-0.208*** (-9.20)	_cons	-0.253*** (-4.14)	_cons	0.0246 (0.42)

sector_other _cons	-0.190*** (-4.50) 0.145** (-2.97)				
N	3587		3579		3579
R-square	0.1399		0.1217		0.0844

Collaboration and innovation each contribute positively to productivity in all three regressions. The results are highly significant which show the strength of this contribution. Innovation has substantially higher contribution to productivity than collaboration. It is wrong to interpret that collaboration is not effective for productivity. Collaboration (besides having direct and positive contribution to productivity) it may have great impact on other factors. Using the conceptual model (introduced in chapter four) we can mention innovation as an example of these factors. Therefore the impact of collaboration in firm should not be underestimated and limited to the above regressions.

By comparing the other two regressions we can see that innovation and has more impact on product and market related effects than on production while collaboration contributes to both equally.

H6.1.1, H6.1.2 and H6.1.3 cannot be rejected therefore:
Product innovation, collaboration contribute positively to productivity (intangible effects)

Product innovation, collaboration contribute positively to productivity (production effects)

Product innovation, collaboration contribute positively to productivity (product & market effects)

H6.2: Product innovation and R&D contributes positively to productivity
productivity_fac_final

H6.2.1: Product innovation and R&D contribute positively to productivity (intangible effects)
Regression Model
productivity_fac_final = β_0 + β_1 innovation_novelty + β_2 rd_fac_final + β_3 size + β_4 age + β_5 multination + β_6 activity_acquire_machinery + $\beta_7$acti vity_training + β_8 activity_market_intro + β_9 market_innov + β_{10} sector_service + β_{11} sector_other

H6.2.2: Product innovation and R&D contribute positively to productivity (production effects)
Regression Model
production_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 rd_fac_final + β_3 size + β_4 age + β_5 multination + β_6 activity_acquire_machinery + $\beta_7$acti vity_training + β_8 sector_service + β_9 sector_other

H6.2.3: Product innovation and R&D contribute positively to productivity (product & market effects)

Regression Model

$$\text{prod_mrkt_related_effect_fac} = \beta_0 + \beta_1 \text{innovation_novelty} + \beta_2 \text{rd_fac_final} + \beta_3 \text{size} + \beta_4 \text{age} + \beta_5 \text{multination} + \beta_6 \text{activity_market_intro} + \beta_7 \text{market_innov} + \beta_8 \text{sector_service} + \beta_9 \text{sector_other}$$

Productivity_fac_final		production_related_effect_fac		prod_mrkt_related_effect_fac	
Innovation_novelty	0.495*** (5.23)	Innovation_novelty	0.374** (3.12)	Innovation_novelty	0.671*** (5.94)
rd_fac_final	0.0891*** (5.78)	rd_fac_final	0.0693*** (3.55)	rd_fac_final	0.120*** (6.75)
size	0.00742 (0.94)	size	0.0257* (2.55)	size	-0.00831 (-0.87)
age	-0.000717 (-0.86)	age	-0.000840 (-0.77)	age	-0.000594 (-0.60)
multination	0.0198 (0.84)	multination	-0.00820 (-0.27)	multination	0.0450 (1.65)
activity_acquire_machinery	0.213*** (9.79)	activity_acquire_machinery	0.363*** (12.73)	market_innov	0.135*** (5.56)
activity_training	0.126*** (4.73)	activity_training	0.119*** (4.22)	activity_market_intro	0.232*** (9.40)
market_innov	0.149*** (7.12)	sector_service	-0.274*** (-9.10)	sector_service	-0.0853** (-3.15)
activity_market_intro	0.0149 (0.56)	sector_other	-0.198*** (-3.84)	sector_other	-0.166*** (-3.44)
sector_service	-0.183*** (-7.94)	_cons	-0.272*** (-4.49)	_cons	0.0101 (0.18)

sector_other _cons	-0.172*** (-4.11) -0.156** (-3.28)				
N	3587				
R-square	0.1426		0.1206		0.0917

Innovation and R&D both have positive contributions to firm's productivity. Innovation is contributing more to product & market related effect of productivity rather than production effects. In contrast R&D contributes more to product & market related effects. Any increase in R&D will thus have impact on product and market related effects (other variables being equal). R&D unit of a firm combines different sets of information ranging from customers, other internal units to suppliers and competitors (market and environment). Using theses sets of information helped firms produce better products (close r to customer expectation) and enter new markets (with help of information about technologies and market). So it is logical that increase in R&D enhances product and market related effects.

H6.2.1 , H6.2.2 and H6.2.3 cannot be rejected therefore:

Product innovation and R&D contribute positively to productivity (intangible effects)
Product innovation and R&D contribute positively to productivity (production effects)
Product innovation and R&D contribute positively to productivity (product & market effects)

H6.3 Product innovation, both intermediate effects and productivity

H6.3.1: Product innovation, collaboration and R&D contribute positively to productivity (intangible effects)

Regression Model

productivity_fac_final = β_0 + β_1 innovation_novelty + β_2 collab_fac_final + β_3 rd_fac_final + β_4 size + β_5 age + β_6 multination + β_7 activity_acquire_machinery + β_8 activity_training + β_9 activity_market_intro + β_{10} market_innov + β_{11} sector_service + β_{12} sector_other

Control variables

The dependent variable is productivity_fac_final which is the same in regression H5.1. Therefore control variables are the same as well as the expectation for their signs.

H6.3.2: Product innovation, collaboration and R&D contribute positively to productivity (production effects)

Regression Model

production_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 collab_fac_final + β_3 rd_fac_final + β_4 size + β_5 age + β_6 multination + β_7 activity_acquire_machinery + β_8 activity_training + β_9 sector_service + β_{10} sector_other

Control variables

The dependent variable is the same as in regression H5.2. Therefore control variables are the same as well as the expectation for their signs.

H6.3.3: Product innovation, collaboration and R&D contribute positively to productivity (product & market effects)

Regression Model

prod_mrkt_related_effect_fac = β_0 + β_1 innovation_novelty + β_2 collab_fac_final + β_3 rd_fac_final + β_4 size + β_5 age + β_6 multination + β_7 activity_market_intro + β_8 market_innov + β_9 sector_service + β_{10} sector_other

Control variables

The dependent variable is the same as in regression H5.2. Therefore control variables are the same as well as the expectation for their signs.

Productivity_fac_final		production_related_effect_fac		prod_mrkt_related_effect_fac	
innovation_novelty	0.492*** (5.21)	innovation_novelty	0.372** (3.11)	innovation_novelty	0.666*** (5.90)
collab_fac_final	0.0353*** (3.36)	collab_fac_final	0.0444** (3.18)	collab_fac_final	0.0294* (2.48)
rd_fac_final	0.0755*** (4.67)	rd_fac_final	0.0509* (2.49)	rd_fac_final	0.109*** (5.83)
size	0.00217 (0.27)	size	0.0201 (1.96)	size	-0.0136 (-1.39)
age	-0.000638 (-0.76)	age	-0.000734 (-0.67)	age	-0.000523 (-0.53)
multination	0.0142 (0.60)	multination	-0.0157 (-0.51)	multination	0.0405 (1.48)
activity_acquire_machinery	0.209*** (9.52)	activity_acquire_machinery	0.355*** (12.42)	activity_market_intro	0.226*** (9.10)
activity_training	0.122*** (4.58)	activity_training	0.112*** (3.97)	market_innov	0.135*** (5.58)
activity_market_intro	0.0126 (0.47)	sector_service	-0.276*** (-9.17)	sector_service	-0.0836** (-3.09)
market_innov	0.149*** (7.11)	sector_other	-0.195*** (-3.77)	sector_other	-0.171*** (-3.53)

sector_service sector_other _cons	-0.183*** (-7.94) -0.173*** (-4.12) -0.133** (-2.75)	_cons	-0.246*** (-4.03)	_cons	0.0312 (0.53)
N	3587		3579		3579
	0.1457		0.1233		0.0937

Results from the table show positive and significant contribution of innovation, collaboration and R&D activity to productivity in all three regressions. First of all I have to note that the range of dependent variables differs and this matter when making comparisons about which variable contributes more to productivity. While collaboration and R&D variables range from -1 to 1 (approximately), variable innovate_novelty ranges from 0 to 1. So a change of 0.1 for innovation _novelty can be weighed as 0.2 change in the other two variables. Although in each puff the regressions above, innovation is by far the largest coefficient already and weighing it higher does not change any conclusion and well remain the highest coefficient.

We start from the first regression. We can see that product innovation, collaboration and R&D activity each contribute positively in increase of productivity (intangible effect). This means that with an increase in any of theses activities, firm's productivity increases. If we look carefully we realize that innovation coefficient is much larger than the other two variables. Innovation is then a very important factor that can enhance productivity. Many firms feel the need to innovate and the number of firms being innovative has been increasing in the last decades. Despite this increase, impact of innovation ion productivity not a clear cut. It is rather a fuzzy issue. From the table we can conclude that firms with that are involved in product innovation increase their productivity by increasing intangible and positive effects. By comparing the second and third regression we can see , like before, innovation contributes more to product & market related effect rather than production effects.

Firms involvement in R&D activity contributes more to productivity compare to collaboration. This means that investment in R&D may pay off better (regarding increase in intangible productivity) rather than collaboration. By extracting results from the second and third regression we can see how R&D and collaboration actually influence the intangible effects. R&D activities increase product & market related effects while collaboration is more influential in production effect.

Sector wise, we have the same result as before. Service sector seems to be less productive than manufacturing. For more information please see regression result H5.

Among the control variables size was expected to have a positive coefficient and the result show the positive coefficient in only the first two regressions. To investigate why size has a negative coefficient in the third regression, I tested its correlation with the other variables. You can see the result in the Table 10 below.

	prod_m~c	innova~y	collab~l	rd_fac~l	size	age	multin~n	market~v	activi~o	sector~e	sector~r
prod_mrkt_~c	1.0000										
innovation~y	0.1383	1.0000									
collab_fac~l	0.1200	0.0099	1.0000								
rd_fac_final	0.1930	0.0755	0.3696	1.0000							
size	0.0210	-0.1513	0.2702	0.2286	1.0000						
age	-0.0180	-0.0780	-0.0273	0.0005	0.0982	1.0000					
multination	0.0471	-0.0109	0.1266	0.0686	0.1583	0.0120	1.0000				
market_innov	0.1401	0.0564	0.0794	0.1097	0.0748	-0.0081	0.0286	1.0000			
activity_m~o	0.2065	0.0259	0.1827	0.2561	0.1079	-0.0322	0.0453	0.1997	1.0000		
sector_ser~e	-0.0661	-0.1116	-0.0656	-0.2166	-0.0657	-0.1861	0.0172	0.0380	0.0213	1.0000	
sector_other	-0.0683	-0.0087	-0.0047	-0.0395	0.0398	0.0523	-0.1192	-0.0653	-0.0283	-0.2647	1

Table 10: correlation matrix

As you can see from the table, all correlation for size is less than 0.6 and thus not high. I chose for this control variable to remain in the regression because there is a relation between productivity and firm age. Therefore omission of this control variable was not wise. One explanation could be the ambiguity of the relation between size of firm and productivity. This is because usually during the firs few years average productivity of firms increase but as the firm becomes older this relation becomes more and more ambiguous (Kok, Brouwer et al. 2006).

H6.3.1, H6.3.2 and H6.3.3 cannot be rejected therefore:
Product innovation, collaboration and R&D contribute positively to productivity (intangible effects)
Product innovation, collaboration and R&D contribute positively to productivity (production effects)
Product innovation, collaboration and R&D contribute positively to productivity (product & market effects)

H7: Product innovation contributes to productivity after a time lag

Regression Model
productivity_labour_ps_p3= β_0 + β_1 innovation_novelty + β_2 size + β_3 age + β_4 multination + β_5 org_innov_structure + β_6 sector_service + β_7 sector_other

In order the possible time lag between innovation and productivity, a financial measure of productivity is calculated as turnover divided by number of employees (fte). In order to have the accurate financial values turnover was first deflated according to the price indexes. These price indexes were different for different years and different sectors. Because of the huge dataset I was not able to join the dataset having the price indices to my panel data. Despite setting the memory to maximum level, the operating system did not allow the link. Therefore average price indices were calculated for each year. This could be done because the indices across different sector in one year did not significantly differ. There was also no year as base which indices could be compared to. Indices were provided to me on a year-by-year basis. This meant that I had to calculate the price index of each year according to all the previous year. Therefore:

Price index for year t = given price index for year t/price index for year t-1 * price index for year t-2* ….

The price indices are given below:

Year	Average Price index
1994	1.03000
1995	1.04798
1996	1.06138

1997	1.08325
1998	1.10064
1999	1.12140
2000	1.16146
2001	1.21294
2002	1.25171
2003	1.27024
2004	1.28697

Control variables

Control variables used for labor productivity are size, age, multination and org_innov_structure. All except the last one have been used for intangible productivity effects as well. Positive sign except for age was predicted for them. Another variable which is influential for labor productivity is org_innov_structure which indicates whether firm has had organizational innovation or not. Any change and rearrangement of structure has an impact on productivity. With the introduction of a new product, organizational structure changes. Firm behavior, culture, short term goal, etc are partially changed in support of new business strategy. These changes occur to help increase flexibility and productivity of the firm. Therefore all β except β_3 are expected to have a positive sign.

	productivity_labour_ps_0	productivity_labour_ps_p1	productivity_labour_ps_p2	productivity_labour_ps_p3
Innovation_novelty	-43269.2*** (-10.48)	-54487.4*** (-12.68)	-5396.2** (-3.26)	-3107.7*** (-5.35)
size	9684.1*** (9.99)	5277.6*** (5.43)	15583.5*** (16.16)	-9734.0*** (-24.17)
age	-318.1*** (-4.82)	-379.9*** (-6.29)	-661.8*** (-8.94)	-8018.3*** (-33.07)
multination	59852.3*** (33.45)	61861.0*** (35.14)	34029.4*** (16.36)	236.9 (0.29)
org_innov_structure	5449.9*** (3.90)	-5395.2*** (-4.64)	- 5373.8*** (-5.48)	3480.7*** (9.05)
sector_service	53665.5*** (17.20)	20507.2*** (6.88)	59283.8*** (18.77)	-1541.0 (-0.34)
sector_other	-7274.5 (-1.95)	-20162.3** (-2.92)	-30189.7*** (-10.93)	-136735.2*** (-26.15)
_cons	101603.2*** (18.94)	129653.6*** (25.41)	89418.1*** (17.96)	303866.9*** (88.85)
N	2189	1211	2325	916
R-square	0.01030233	0.01728607	.01433018	.00156963

In the above regressions productivity is measured financially. Result from the table show that product innovation is negatively and significantly related to labor productivity. Across the four different regressions we can compare innovation's contribution to productivity. In t=0 (the same year firms had product innovation) productivity decreases. The coefficient is large but negative. At t=1, one year after product innovation productivity is decreasing further. At t=2 productivity starts to decrease but very slightly. It is not until t=4 that productivity although still negative, it starts increasing dramatically.

The negative result can be attributed to all the capital stock and the investments. Product innovation requires huge investments in R&D, machinery, training, technology (including ICT) , etc. According to the result only in the fourth year firm starts to move toward financial recovery. Of course this conclusion is only valid if results for more years after product innovation verify the increase in productivity. Further investigations (with extension of time horizon) can clarify the issue. For now we can conclude that although we haven't found a time lag for when product innovation leads to productivity, we can say that at least for three years after product innovation, productivity decreases substantially.

H7 cannot be rejected therefore:
Product innovation doesn't contribute to productivity after a time lag.

H8: ICT usage together with the intermediate effects contribute positively to productivity

Regression Model

productivity_labour_deflated= β_0 + β_1 interaction_rd_integ + β_2 interaction_rd_aut + β_3 interaction_collab_co + β_4 size + β_5 age + β_6 multination + β_7 org_innov_structure + β_8 sector_service + β_9 sector_other

Control variables

Dependent variable in this regression is labor productivity which is the same as the previous regression. Therefore all the control variables are the same. Positive signs are expected for all control variables except age.

productivity_labour_deflated	
interaction_rd_integ	20292.0*** (4.71)
interaction_rd_aut	20666.2*** (5.21)
interaction_collab_co	7677.2** (2.72)
size	38498.0*** (13.91)
age	-463.0*

	(-2.45)
multination	5758.6 (1.06)
org_innov_structure	2636.9 (0.66)
sector_service	-21322.7*** (-4.25)
sector_other	85982.5*** (6.78)
_cons	-52853.3*** (-3.52)
N	430
R-square	.00034146

Three variables are used in this regression and their contributions to them are at focus. Interaction_rd_integ is a variable that shows the combination of R&D activity with integration role (category 3 ICT). interaction_rd_aut indicates the co-existence of R&D activities and automation role (ICT category 2) and finally interaction_collab_co shows the simultaneous existence of collaboration and communication_coordination role (ICT category 1). The table shows positive contribution of each of these variables to productivity. Each coefficient is a large positive number. Therefore the coexistence of roles and the intermediate effects are important. It is interesting to see that generally R&D activity together with ICT roles contribute substantially more (larger coefficient) than collaboration with its relevant ICT role. This I think can be explained due to the extent of these two activities. For product innovation firms don't necessarily collaborate but their R&D department is completely engaged with the process of the product development. Consequently the ICT tools used for R&D serve larger number of activities. Therefore coexistence of R&D and relevant ICT applications covers a larger number of activities along product innovation. In this way they contribute more to productivity than collaboration.

The distinction between R&D and the two roles (automation and integration) is not large. They seem to contribute almost equally to productivity.

In short, increase in any of the intermediate effects together with its relevant ICT applications results in increase in labor productivity.

H8 cannot be rejected therefore:
ICT usage together with the intermediate effects contribute positively to productivity

Summary of Empirical analysis:
The empirical results which were based on the designed hypotheses are given in the table below. Whenever the result of a regression is significant the null hypothesis is rejected. Null

hypotheis is based on unequality or absence of correlation. Therefore in each of the regressions discussed null hypothesis explained the absence of correlation. In case of significance of result this null hypotheses is rejected. And this means that there is a relation between the tested constructs. This will be the interpretation of the hypotheses designed to test the model.

Hypothesis	Research result
H1.1: Category one ICT applications are positively related to collaboration	Not rejected
H1.2: Communication role and coordination role (roles of ICT applications from category one) are positively related to collaboration	Not rejected
H2: Category two and three ICT usage are positively related to R&D	Not rejected
H3: Intermediate effects contribute positively to product innovation	Not rejected
H4: category one ICT usage and collaboration contribute positively to product innovation	Not rejected
H5.1: Product innovation contributes positively to productivity(intangible effects)	Not rejected
H5.2: Product innovation contributes positively to productivity(production related effects)	Not rejected
H5.3: Product innovation contributes positively to productivity (product & market related effects)	Not rejected
H6.1.1: Product innovation, collaboration contribute positively to productivity (intangible effects)	Not rejected
H6.1.2: Product innovation, collaboration contribute positively to productivity (production effects)	Not rejected
H6.1.3: Product innovation, collaboration contribute positively to productivity (product & market effects)	Not rejected

H6.2.1: Product innovation and R&D contribute positively to productivity (intangible effects)	Not rejected
H6.2.2: Product innovation and R&D contribute positively to productivity (production effects)	Not rejected
H6.2.3: Product innovation and R&D contribute positively to productivity (product & market effects)	Not rejected
H6.3.1: Product innovation, collaboration and R&D contribute positively to productivity (intangible effects)	Not rejected
H6.3.2: Product innovation, collaboration and R&D contribute positively to productivity (production effects)	Not rejected
H6.3.3: Product innovation, collaboration and R&D contribute positively to productivity (product & market effects)	Not rejected
H7: Product innovation contributes to productivity after a time lag	Rejected
H8: ICT usage together with the intermediate effects contribute positively to productivity	Not rejected

Table 11: Empirical Results

Before moving on to the conclusion chapter, some empirical results will clarify the constructs regarding the different sectors. From the above empirical analysis we saw that service sector was less innovative and productive compared to manufacturing sector. It is interesting to examine the issue in our dataset over a number of years.

First let's depict the ict usage across sectors. The following graph (Figure 11) shows the ICT usage per sector. ICT usage is constructed from ICT roles. If a firm uses either of ICT applications (attributed to roles) then it has ict_usage. Therefore ict_usage has the value of 0 or 1.

To be able to show the ict_usage on graph sum of the ict_usage variable is shown on the Y axis. Sectors are shown on the X axis.

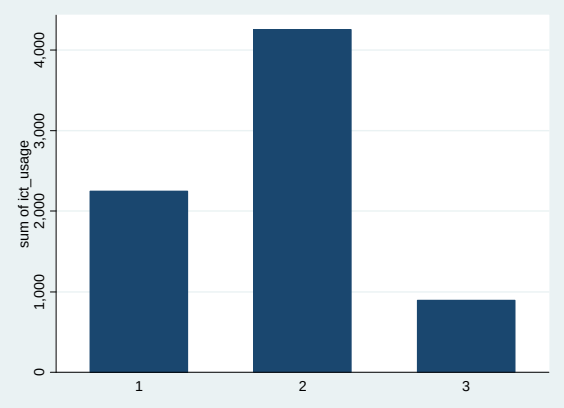
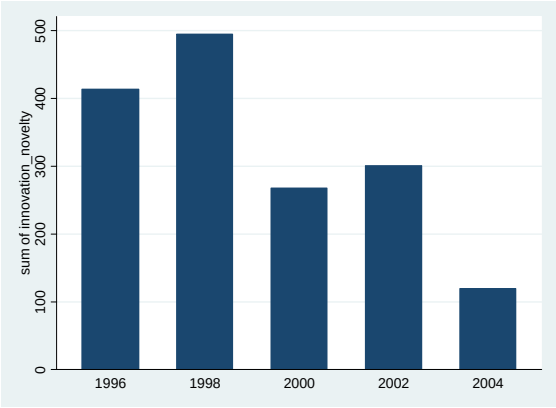
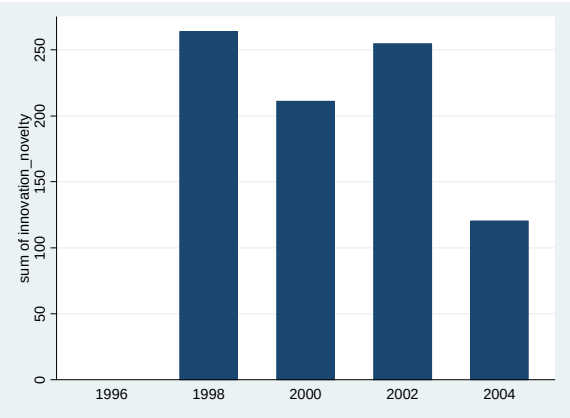


Figure 11: ICT usage across sectors
1: manufacturing 2: services 3: other

From tehgrpah we can see that service sector uses ICT much more than manufacturing sector. The difference is quite substantial. Unfortunately it was not possible to depict ICT usage across time axis for each sector. This is because of the structucture of our panel data. The data is defined based on CIS years which is every two years starting from 1996. In each of these years, data from several years of ICT are gathered (data attributed to a few years before every CIS year). Therefore separating ict usage for different years is not possible. For example year CIS=1996 shows ict usage of firms from 1993 till 1996 and the data for each of these years is not separable. We could not see the trend of ICT usage across time but this is possible for innovation and prodcutivity.

So see the situation for innovation and prodcutivity.
In the following graphs (Figure 12) we can see that service sector is less involved in product innovation than manufacturing sector (notice the difference in intervals of y axis on each graph). The empty space for year 1998 in service sector is due to lack of data[4]. Generally we can see a decrease in innovation in both sectors. Of course with extension of years a more reliable judgment can be made. So we can see that Dutch firms have generally been less innovative since 1998.



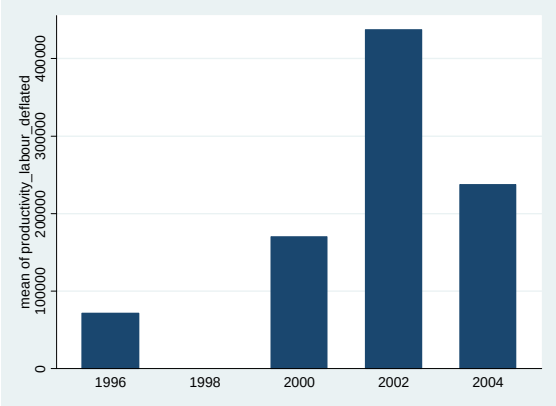


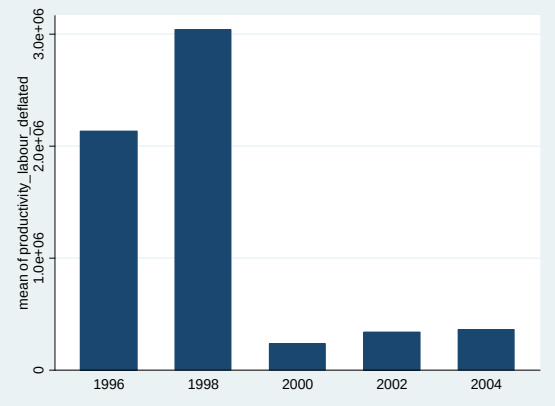
Innovation in manufacturing sector Innovation in service sector

Figure 12: Innovation across time

[4] In order to calculate innovation novelty, percentatge of new products divided by total turnover was calculated. Turnover of new products was not available for firms in service sector in 1998.

Now let's see the trend for productivity. I was not able to calculate prodcutivity for manufacturing sector due to lack of data[5]. In following graphs we can see that the general trend in each sector is an increase in productivity from 2000 onwards. We concluded from the tables that service sector is less productive than manufacturing sector. The intervals of y axis which shows the productivity in two graphs are different. Therefore the bars from two graphs are not comparable. To make the comparison easy the following table is provided which shows the productivity (from graphs) in numbers.





Labor Productivity in manufacturing sector Labor Productivity in service sector

Figure 13: Productivity across time

From the table we can see that except in 1996, productivity of both sectors is approximately the same.

year	1996	1998	2000	2002	2004
Labor Productivity in manufacturing sector	0.1	-	0.18	0.42	0.22
Labor Productivity in service sector	2.1	3	0.2	0.4	0.5

The following graph (Figure 14) gives an overview for each sector. ICT is more frequently used in the service industry while productivity (intangible) is highest in the manufacturing sector.
Innovation novelty is higher is slightly high in manufacturing compared to services but productivity is much higher in service sector.

So we can conclude that although ICT is more used in service but the innovation in service in lower compared to manufacturing. We can also conclude that although ICT is used more in service the productivity is almost the same as manufacturing sector.

Therefore we can conclude:
Although service industry is less innovative and has almost the same productivity (as the manufacturing) it uses ICT much more frequently than manufacturing.

[5] In order to calculate productivity, I had to divide turnover to number of employees. Number of employees was not available for year 1998 for manufacturing sector.

The following graph (Figure 14) shows ict usage, innovation and productivity for different sectors. Here intangible effects of productivity are depicted. Intangible effects of productivity, is approximately the same (just like labor productivity).

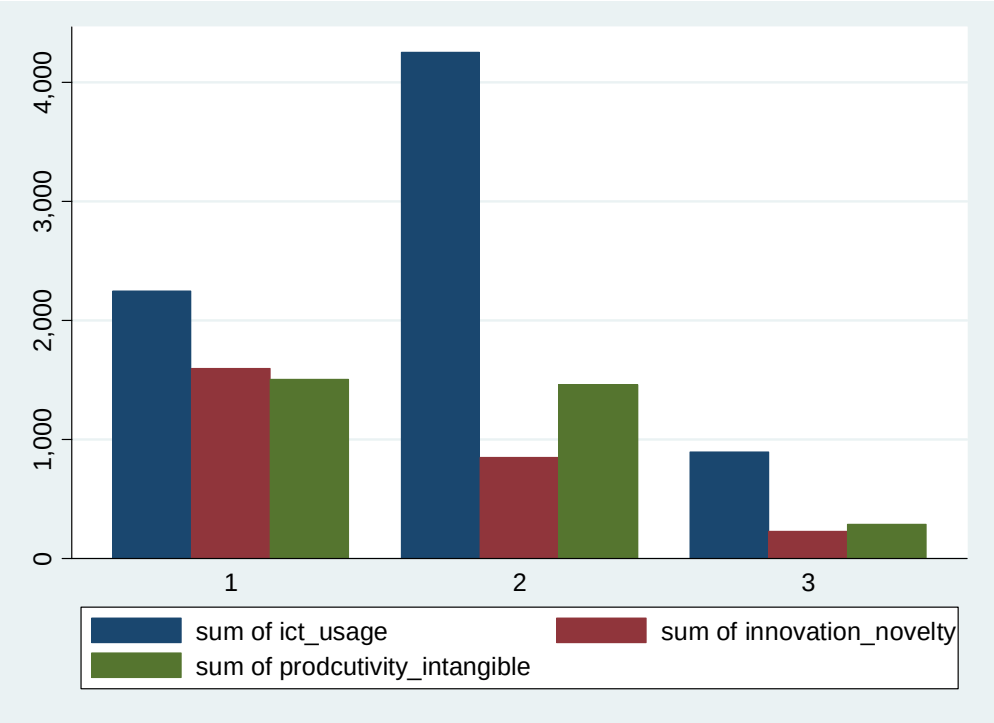


Figure 14: ICT usage, innovation and productivity across sectors
1: manufacturing 2: services 3: other

From these graphs it can e concluded that although productivity of firms in service sector is approximately the same as those of manufacturing, service sector's ict usage is much higher. This makes the service less efficient in using ICT. In other words, the growth on productivity for service sector is much slower compared to manufacturing sector.

Brynjolfsson (1993) found out that productivity growth in service sector is slower than manufacturing[6] . The reasons mentioned are measurement problems, mainly:

- Many service transactions are idiosyncratic, and therefore not subject to statistical aggregation.
- Some variable was left out of the equation

To generalize we can conclude that manufacturing sector has made better use of ICT than service. This is consistent with argument of Roach and he argues that the reason is that manufacturing faces greater international competition.

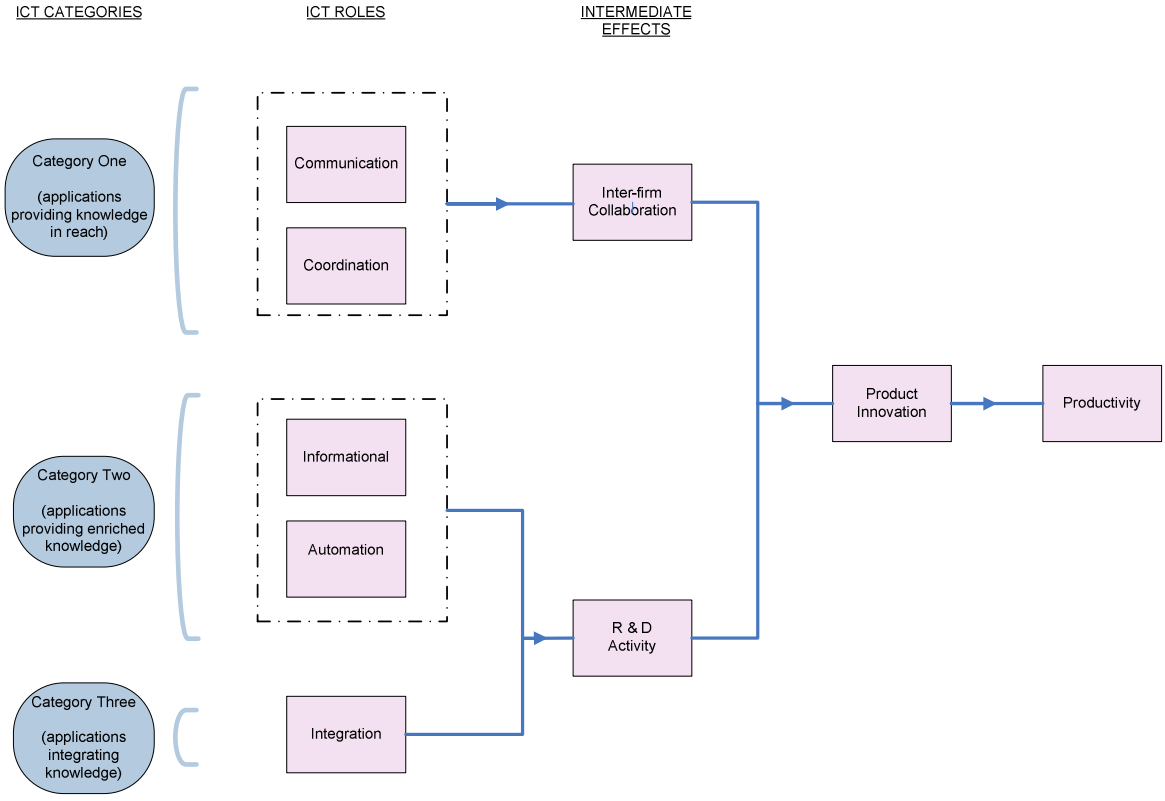
[6] this was concluded regarding ICT investment but same argument is valid here because ICT is used much more often and it is predicted to enhance productivity more than manufacturing which is not the case.

8 Chapter eight: Conclusions & Implications

Motivation: This chapter summarizes the findings and contributions of this study. It starts with the general academic conclusions which are followed by managerial implications. A discussion is then provided to give a general overview of where this research stands compared to other studies done in the same field. Later the limitations of the study are discussed and at the end of this chapter recommendations for future research are provided.

8.1 Academic Implications

This study was conducted to contribute to the body of literature regarding productivity paradox and more specifically ICT business value creation. Through comparison of various models provided by other researchers as well as conducting extensive literature studies, the following integrated model was provided in chapter four and was consequently tested.



Out of eight hypotheses which were designed to test certain part of the model, surprisingly only one hypothesis (H8) was rejected. In addition all results except only H1 were significant. Therefore the model seems to be academically valid and reliable. Rejection of only one hypothesis out of so many the for one specific model is not very common. The model was of course based on literature study and previous work of many researchers, but empirical results as we know, are not always aligned with our

theoretical expectations. One reason for having such good empirical result in this research was the use of panel data. Panel data is a form of longitudinal data. Longitudinal data include observations of same firms at different times. Longitudinal data is very appropriate for studying ICT value creation. This is because the time frame enables the learning effect and organizational changes necessary to exploit ICT investments and also the flexibility of firms using ICT to be taken into consideration. Therefore more accurate results can be provided through longitudinal data. The time range used in this research was from 1996 till 2004.

This research, as mentioned before was conducted to shed more light on productivity paradox which states that "increase in ICT investment does not necessarily increase productivity". From the research that was carried out I conclude that in the Dutch sector ICT usage has increased productivity and therefore ICT enhances productivity among the Dutch enterprises. This relationship is enhanced through the roles that ICT applications play and also the intermediate variables of collaboration and R&D and through innovation (namely product innovation).

ICT applications cover a broad range of applications in a firm. One contribution of this study was to provide a useful, theoretical and at the same time practical classification of ICT application. This classification is based on the various roles that ICT play in a firm. These roles are communication, coordination, information (first level processing), automation (second level processing) and integration. This classification includes three different categories of ICT applications:

Category One: ICT applications providing knowledge in reach. These applications enhance communication and coordination role of ICT.

Category Two: ICT applications providing enriched knowledge. These applications enhance information and automation role of ICT.

Category Three: ICT applications integrating knowledge. These applications enhance the integration role of ICT.

The new classification enables a better understanding of the level in which ICT is used and it's linkage to the level where its impacts occur. Moreover the proposed model adds to the literature on ICT value and provides a better understanding of how this value is created.

Category one enhances collaboration while category two enhances R&D activities. To be more specific regarding the ICT roles, ICT tools of category one which enable and/or enhance both communication and coordination improve firm's collaboration. Although empirically this link was not strong (significant) but there was a positive relation between category one and collaboration. Between the two roles of category one, tools enhancing communication role were found to be more effective for collaboration than ICT tools enhancing coordination.

While category one applications influence collaboration, category two and three enhance R&D activities. Firm using ICT application from category two is called automated i.e. its first and second level processes are done through ICT applications. For example simulation applications provide a 3 dimensional environment provide a more

specific view of product being developed. This of course is a huge enhancement in speed as well as quality of product development. When comparing the impact of category two and three on R&D we realized that category three has more influence on R&D. In other word knowledge integration is more important for R&D than automation of processes. This shows the importance of knowledge integration. Firms in the manufacturing sector seem to be more collaborative when innovating (product innovation) compared to service sector.

Another finding is that the more the firm is collaborative and engaged in R&D activities the more innovative it will be (with regard to product innovation). The impact of collaboration is higher compared to R&D activities. Collaboration with different partners internally or externally leads to higher number of new products. Collaboration brings firms closer to their partners and consequently results in increase in quality or leads to a new but demanding product. For example by collaborating with customers, firm becomes closer to customer's expectations. R&D activities may include the whole process of product development except production. R&D department uses all kind of information (from customers, suppliers, market, competitors and even other departments of the firm) and conducts tests and simulations which all result in innovation (improve in quality or completely new product).

Another contribution of this study was the consideration of intangible aspects of firm performance. In order to examine the productivity paradox, intangible effects of ICT are often ignored or not at all gathered in datasets. I had the opportunity to have access to variables which were indicators of intangible effects. Using these variables I realized that increase in innovation influences intangible effects. Firms having product innovation increase intangible effects positively. The impact of product innovation on product & market related effects are much larger than production related effects. Product & market related effects include improvement in quality of new product, increase in range of product and entrance to new market. Production related effects relate to increase in flexibility, capacity & decrease in material usage. So with development of new products, firms increase product quality & range and their market territories.

Firm's engagement in product innovation, collaboration and R&D enhance its productivity, regarding intangible effects. Innovation has larger impact on market & product related effects while R&D improves production related effects more. Collaboration increases both effects equally.

One other contribution of this study was to investigate the possibility of time lag between innovation and productivity. Four different periods within eight years were chosen (every two years from 1996). Innovation was found to have negative impact on productivity for all four periods. For neither of the four years a positive relation was found and the time lag assumed for the enhancement of productivity through precut innovation was not found. However substantial recovery was seen in productivity of firms in the third year after their product innovation. I cautiously predict that the fourth year after product innovation, positive results will be shown and consequently the time lag of four years may exist. In other words I predict that productivity is enhanced through product innovation after four years and not sooner.

One important implication of this study is that the intermediate effects together with ICT application increase productivity. What I mean is that the co-existence of intermediate effects and the attributed ICT roles enhance productivity. Therefore their co-existence is essential. To be more specific regarding our conceptual model I conclude that firms involvement in R&D activities and usage of category two and three increases productivity much more than firms involvement in collaboration and usage of category one ICT. This I think can be explained due to the extent of these two activities. For product innovation firms don't necessarily collaborate but their R&D department is completely engaged with the process of the product development. Consequently the ICT tools used for R&D serve larger number of activities. Therefore coexistence of R&D and relevant ICT applications covers a larger number of activities along product innovation. In this way they contribute more to productivity than collaboration.

We have also extensively compared manufacturing sector with service sector. Service sector is less collaborative, innovative and productive than the manufacturing sector. In the manufacturing sector process of new product development includes many stages starting from idea generation, to design and production. Firms can collaborate in each of theses phases. Collaboration with customers occurs in stages before idea generation while collaboration with suppliers occurs while the product is ready to be produced and later delivered. Compared to the service sector, new service (as product) does not usually involve the aforementioned phases and thus requires relatively less collaboration. Regarding the sectors, firms in the service sector are generally less engaged in R&D activities.
According to our results firms in service sector are less innovative compared to the manufacturing sector. This result is aligned with statistical evidence showing that only in few and limited areas service sector is more innovative than manufacturing sector (Sheehan 2006).
Productivity on service sector is much less than manufacturing. There is evidence from CIS3 about this difference. According to a study based on CIS3 market based services in Netherlands account for more than 45% of total value added in 2001 (Sheehan, 2006). Although this is a huge, it is not the majority of share. In addition, many manufacturing firms have linked their products to services by providing clients with product-services packages and integrated solutions (Sheehan, 2006). So their share is also included in the 45%.

In short, the conceptual model proposed seems to be reliable theoretically as well as practically. It shows how ICT influences productivity through innovation. In turn innovation is influenced by intermediate effects of collaboration and R&D activities.

Sector wise, although ICT is more frequently used in service sector, firms in service sector seem to be less innovative than manufacturing but productivity of firms in service sector is almost the same as manufacturing sector. We can conclude that manufacturing sector has made better use of ICT than service sector. This is consistent with argument of Roach arguing that manufacturing sector faces greater international competition.

Main Message

Now we will glance back at the research questions proposed in the fist chapter.

Main Research Questions:

1. Are ICT, innovation and productivity related?

2. What are the mechanisms through which ICT influences innovation and consequently firm productivity?

The answer to the first question is positive. In fact ICT, innovation and productivity are correlated. I can conclude that this correlation is positive. Therefore ICT enhances innovation and consequently productivity.

The answer to the second question is as follow: There are certain mechanisms in the ICT value creation which enhance innovation and consequently productivity. Two important mechanisms are collaboration and R&D. Through these two factor, ICT impacts innovation and consequently productivity.

As a general remark I have to mention that productivity paradox does not exist (at least not among Dutch firms). This conclusion is derived from extensive empirical analysis which has supported this study. Several strong points of this study are as follows.

- This study was conducted on panel data thus including many years and is capable of providing a more accurate conclusion.

- ICT usage was considered instead of ICT investment which is believed (by other researchers as well) to provide more accurate result.

- Intangible effects of ICT on productivity which are rarely available in datasets was used to capture more aspects of productivity.

In the next section a comparison between our conclusion and the result of other studies is discussed.

8.2 Discussion

As mentioned in the first chapter the motivation and origin of this research has been the productivity paradox. This paper focused on the relation between ICT and productivity and has consequently added to the body of literature about ICT value creation. In this section results from other researches regarding the general theme of productivity paradox is compared to the result of this paper.

Weil has argued that ICT is not a homogeneous entity and has to be broken down into different categories when studying its relation to productivity (Weill 1990) and (Weill 1992). Although his argument was addressing ICT "investment", the same holds for ICT usage. This is because ICT is a broad subject and dealing with ICT as a whole, leads to ambiguous and controversial results. This paper is aligned with Weil in the sense that ICT is not regarded as one broad entity.

Our perspective in this paper can be aligned to that of Clayton et al (2003) and Kollinger (2005) which mention that performance should be linked to ICT-enabled innovation not ICT endowment. In other words what firms do with ICT is important rather than whether they have ICT. In our study we have focused on ICT usage rather than investment.

Our result is closely related to that of Barua (1995). He used a process oriented methodology and conducted a two stage analysis of intermediate and higher level output. He concluded that ICT has significant and positive influence on the intermediate level. These intermediate level variables are capacity utilization, relative price, inferior quality and new products. These intermediate variables were then showed to have impact on output performance. In the current paper we used innovation as the intermediate variable which indicated new products that firms produce. We further broke the intermediate level down and investigated ICT relation to variables of R&D and collaboration. We found positive results between ICT, the intermediate effects, innovation and productivity in general.

Positive relation between ICT and firm performance, aligned with our results, was found by many researchers. Weil (1992) found positive contribution of ICT to productivity in manufacturing sector. Positive relation between several organizational performance and ICT was found by Mahmood and Mann (Mahmood and Mann 1993). Our result is also aligned with study of Brynjolfsson and Hitt (1996) concluding that spending has statistically significant contribution to firm output. Radhann Krishnan et al found empirical support for the differential business value created by IT along a number of process oriented dimensions (Radhakrishnana, Zub et al. 2005).

Our conclusion is however not consistent with many studies which have shown negative results for the ICT contribution to firm performance. Roach (Roach 1988) showed that output per production worker grew by 16.9% between mid-1970s and 1986, while output per information worker decreased by 6.6%. Berndt and Morrison (1994) concluded that there was a statistically significant negative relationship between productivity growth and the high-tech intensity of capital investments.

With regard to innovation, many studies have shown a positive relation between ICT and innovation. Gordon et al showed that Information systems can help with collaboration, knowledge sharing, competitive intelligence, and in many other ways to help people generate ideas that are both creative and potentially valuable (Gordon, MonideepaTarafdar et al. 2008). Delgoshaie (2007) showed that each of ICT roles have positive effect on product, process and organizational innovation.

There are also studies which show a negative relation between innovation and ICT. Information technology can also hamper innovation (Johannessen, 1994). This happens if the use of IT generates a segmentalistic culture. According to Kanter (1983) innovation needs an integrative culture rather than segmantic. On the other hand many researchers have suggested other main reasons for ICT to hamper innovation such as information overload.

With more availability of data at firm level, and the increase in number of studies, better comparisons could be made. Consequently sound conclusions can be derived from detailed and statistical analyses.

8.3 Managerial Implications

This paper has practical implications which are deducted from the conclusion drawn in the previous chapter. These implications are aimed to assist managers in reaching a better understanding about ICT usage and its effects in their firm as well as recognizing possible problems or lacks in their business process preventing them from gaining optimal results. In addition these implications assist mangers in recognizing the first step for reaching better results.

1. *ICT usage pays off*

The long lived paradox of productivity has faded away. The paradox questioned whether ICT investment enhances productivity. This study conducted on a huge and unique sample of Dutch firms in a time period of a decade and concludes that ICT applications do make a difference in your firm's productivity. So any decision about further ICT investment should not be hindered because of the doubt in productivity enhancement. Of course the investment should follow a guideline and be aligned to your firm's vision and goal. So we assumed you know which ICT investment might be fruitful for your firm and your only doubt is whether to invest or not.

2. *There are three ICT categories to invest in*

This study introduces a new classification on ICT which is believed to be unique and practical. It is based on the roles and impacts of different ICT tools. This classification gives you the right view about what you ICT tools is being used in your firm as what might have more or less been ignored. Three categories are:

Category one: ICT applications which provide accessibility of knowledge
Category two: ICT applications which enrich knowledge (process data)
Category three: ICT applications which integrate knowledge (by integration of different activities, units or processes)

3. *ICT is a tool to enhance collaboration*

You can use certain ICT applications to enhance your collaboration with your partners. Category one application is most suitable for this goal. ICT applications belonging to this category enhance communication and coordination in firms. Applications with the primary role of enabling or enhancing communication enhance your firm's collaboration much more than applications with primary role of creating coordination.

4. *ICT is a tool to enhance R&D*

ICT tools can enhance your firm's R&D activities. If you are aiming to increase your firm's R&D activities, ICT applications belonging to category two and three are the most appropriate. ICT belonging to category two automate your firm. Therefore first level and second level processing will be done through ICT applications. On the other hand, ICT applications belonging to the third category, integrate different units and bodies of knowledge at your firm. In this was an integrated system is created where R&D activities

are substantially enhanced. Category three applications are more influential on your firm's R&D activities; therefore using more tools from this category is wise.

5. ICT is a tool to enhance product innovation

ICT can enhance your product innovation. Use of ICT enhances product innovation. ICT enhances different capabilities your firm needs in order to be successful in innovation. When your firm is involved in cooperation (internally or externally) there are certain ICT tools that enhance the work efficiency. These support the workflow, communication and coordination for the cooperating parties. For successful product innovation, ICT offers many technical tools that help the design process such as prototyping, simulation tools. In addition different information received from the environment (customers, suppliers, competitors, market) together with useful and relevant internal information need to be integrated in order to enhance efficiency and recombination of knowledge for a new product. The bottom line is that ICT supports different processes and activities that lead to product innovation.

There are three categories introduced in chapter three of this research. In order to produce a new product successfully you need to be using all these ICT application. Of course a right combination is firm specific and contextual.

6. Each set of ICT application plays a different role and consequently has a different impact on your business.

ICT applications vary in the impact they have. Assuming you have enough information about your firm and its strategy you can make a decision about which ICT application is not being used sufficiently. In the context of product innovation, you cab consider two different activities influential for innovation: collaboration and R&D. If your firm is not efficient in collaboration and you would like to improve it significantly, the appropriate ICT tools to is use belong to category one. There is either lack of support for coordination, coordination or both.

If your R&D performance is poor, the initial ICT tools that can enhance this performance belong to category two and three. You need to use the correct combination of automation tools for data processing, maintenance and security as well as internal and external integration systems such as ERP or CAD.,

7. All three categories of ICT are important

The three categories introduced in this research have different implications for your firm. Having the right combination of all these three categories is important for both innovation and also productivity enhancement. Based on your firm's vision, goal, strategy and context (industry) you can find the suitable combination. There are two important remarks to make:

- What is important is that ICT applications when used, complement each other. For example communication and coordination (category one) use different first

level processing of storage and retrieving (category two). This effect is more meaningful when numerous ICT applications are used.

- There are several ICT applications which conduct different roles simultaneously. So they belong to two or all three categories of ICT at the same time.

Taking these two remarks into account, ICT applications are all important and should be taken into account simultaneously.

8. Innovation investments don't pay off immediately

Investments in innovation do not necessarily enhance productivity in the same year. According to this study your firm's innovations influence your firm's productivity negatively and substantially. This negative effect decreases enormously in the fourth year after product innovations. Thus if you are investing in product innovation, you should be aware of possible disappointing results for that year and a minimum time lag of one year before you really see the effect of your investment.

9. ICT enhances productivity by enhancing intangible effects

ICT enhancement in your firm should not only be measured by financial measures such as productivity but also by comparison of intangible effects. This study showed that there ate two main intangible enhancements achieved through ICT. One is internal and related to production process of your firm. By using ICT you enhance the production process flexibility and capacity. On the other hand ICT impacts market related effects. These effects include increase in range of products and entry to new markets. In addition ICT enhances product quality.

Thus when looking for ICT effects, ignoring its intangible effects does not lead to correct judgment.

10. Manufacturing sector is more innovative and productive

If your firm does not belong to the manufacturing sector, it is very likely for your firm to be using ICT inefficiently. You should not judge the innovativeness and productivity by regular figures provided for all sectors. Manufacturing sector is much more intense regarding product innovation compared to service and other sectors. Productivity, both economic output and intangible effects are much more enhanced in manufacturing sector compared to the other sectors.

8.4 Research limitations

This research has been limited from different aspects and has faced several limitations in the process of its completion. Each of these aspects will be discussed below.

8.4.1 Scope limitations

This paper was focused on micro economic level (firm level). Although it is very valuable to have an analysis in this level, the disadvantage is that firm was analyzed as an isolated entity. The scope of this paper was limited to firm boundaries and any external factor such as policy and social issued were completely ignored.

8.4.2 Data limitations

Although the dataset used was a panel data, there were limitations regarding the dataset. Questions on surveys were relatively short and unexplainable. Therefore the answers of respondents could have been in many cases subjective. For example whether firm innovates permanently or rarely can have controversial answer for one firm. One respondent may regard once a year innovation as permanent while another may regard once a month innovation as permanent innovation.

Another limitation was lack of variables (such as capital and ICT investment). Although gathering all kinds of variables is not efficient and hardly possible, it still sets a limitation for the researcher.

The data set included only Dutch firms. Thus the results are only attributed to Dutch firms. Thus the result can not be generalisable.

8.4.3 Measurement limitations

As mentioned before, answers to questions on surveys may not be reliable and consistent. Although careful data consistency and data cleaning has been conducted to prevent these errors as much as possible, no intervention has been done to data.

The price deflators used in this paper were constructed as “average” price index of all sectors for every year. This average is obviously not an exact measure especially for all the sectors.

8.4.4 Methodology limitations

In the theoretical section of this paper there has been many limitations. First of all ICT impact has been captured in a few elements (two intermediate variables and innovation). In firms ICT impact does not limits to these few modules. The interrelation between all the modules has been completely ignored. Similarly the interrelations between ICT categories and consequently ICT roles have been ignored as well. The backward loop from innovation to ICT or from Productivity to ICT or innovation and many other possible backward paths are ignored. There is also a possibility of loops in the model which was not analyzed.

Also in the empirical section, there are many limitations. Use of capital stock in productivity regressions will certainly lead to more accurate results. Use of

Simultaneous Equation Modeling, testing many regressions simultaneously can provide more accurate results. Many part of the model was not tested and the relations between all modules have not been empirically tested.

8.5 Recommendations for further research

Because of time limitations the introduced conceptual model was not completely tested. There are many relations between the modules that have to be tested. The hypotheses tested covered only a limited number of relations. Considering the fact that the model seems to be sound, it is recommended to test the model thoroughly.

External factor at meso-level or macro-level can be added to the model and their impact can be further investigated. Contextual analysis and the comparison between different contexts can also be studied which may lead to interesting and plausible results. Interrelations between modules for example between different ICT categories or even ICT roles can be investigated and later on empirically tested. Investigation of possible loops in the model can be extensively investigated for example the loop from productivity and ICT roles.
All results can be compared to similar results of other countries. In this way general conclusions can be drawn.

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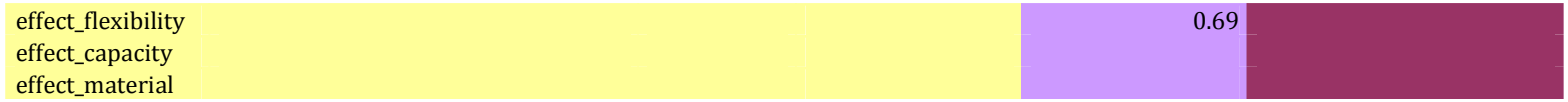
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Appendix A: Factor analysis overview

The yellow shaded variables are factored together while the blue variables are mathematically combined together in order to come up with one variable. The purple shade shows the final factor in each set of variables.

Coomunicatio & Coordination	Variable	Label		First_order_factor_alpha	Second_order_factor_alpha	Third_order_factor_alpha
Internal communication	tcp/ip		commu	ALL ONE VAR	0.404	0.5
	LAN	LAN?	commu			
	NETW_OV	Niet-TCP/IP-netwerken?	commu			
			commu			
external communication	EXT_NETW	Gebruikt externe netwerken?	commu			
e-commerce	EL_INKP	Elektronische purchase from supp	coordination	0.71		
	EL_VERKP	El. Receiving orders from customer				
	EL_LEVER	Elektronische delivery to customer				
	EL_SERV	El. After sale service to customers?				
	ICT_SYST	ICT order-systemen?				
Information & Automation						
internet security & data maintenance	BV_SERVR	Beveiligde webserver?	info	ALL ONE VAR		
	BV_FWALL	Firewall?	info			
	BV_VIRUS	Antivirus?	info			
	BV_UPD	Update beveiliging?	info			
	BV_BACK	Off-site back-up?	info			
	BV_ENCR	Encryptie?	info			
	BV_ID	Identificatiesysteem?	info			
	BV_SIGN	Digitale handtekening?	info			
	automat		auto	ALL ONE VAR		
Intergration					0.591	
internal system integration	KOPP_VRD	storage administration system?	integration	0.801		
	KOPP_FAC	payment system	integration			
	KOPP_PLN	production planning system	integration			

	KOPP_LOG	logistics planning system	integration		
	KOPP_MRK	marketing planning system	integration		
external system integration	KOPP_KL	customers' business system	integration	0.769	
	KOPP_TOE	suppliers' business system	integration		
			integration		
Collab					0.64
internal	co_within_concern	collaboration with enterprises within enterprise group			
external	co_client	collaboration with clients or customers		0.866	
	co_supplier	collaboration with suppliers			
	co_competitor	collaboration competitors			
	co_private	collaboration with private institutes			
	co_uni	collaboration with universities			
	co_public	collaboration with public and semi-public institutes			
R&D					0.596
	activity_intramural_rd				
	activity_extramural_rd				
Innovation					
	novelty				
Productivity					0.485
	effect_range_prod			0.689	
	effect_new_market				
	effect_quality				


effect_flexibility
effect_capacity
effect_material
0.69

Appendix B: Questionnaires

ICT Questionnaire

contactpersoon Contact Center CBS
doorkiesnummer (045) 570 64 00
correspondentienummer
ons kenmerk BWV-S-27-05
onderwerp ICT-gebruik bedrijven 2004
bijzonderheden

Geachte heer/mevrouw,

Hierbij zend ik u de vragenlijst ICT-gebruik bedrijven 2004. Bijna alle vragen van deze vragenlijst kunnen met een eenvoudig 'ja' of 'nee' worden beantwoord.
Het CBS verzamelt jaarlijks gegevens over de automatisering en de toepassing van informatie- en communicatietechnologie (ICT) bij bedrijven. Ditzelfde onderzoek wordt ook in de andere landen van de Europese Unie gehouden zodat de situatie in Nederland goed vergeleken kan worden met die in de ons omringende landen.

Het gebruik van ICT wordt van belang geacht voor de concurrentiekracht van het Nederlandse bedrijfsleven, niet alleen onderling, maar zeker ook ten opzichte van de ons omringende landen. De uitkomsten van dit onderzoek dienen onder meer als referentie voor overheidsbeleid en wetenschappelijk onderzoek en worden ook veelvuldig gebruikt door bedrijven en brancheorganisaties.

Actualiteit van de genoemde gegevens is van groot belang. Ik verzoek u de aangehechte vragenlijst vóór de daarop vermelde terugzenddatum, ingevuld te retourneren. Hierbij kunt u gebruik maken van bijgevoegde retourenvelop.

De uitkomsten van deze en andere enquêtes kunt u bekijken via de CBS-website www.cbs.nl

Als u naar aanleiding van deze enquête vragen heeft, kunt u contact opnemen met één van de medewerkers van bovengenoemd Contact Center.

Voor uw medewerking dank ik u bij voorbaat.

Hoogachtend,
Hoofd Sector Waarneming Bedrijven Voorburg

Drs. R.H.M. Smulders

CBS Voorburg

Prinses Beatrixlaan 428
Postbus 4000
2270 JM Voorburg

Adreswijziging

Indien de tenaamstelling en/of adressering niet correct is, verzoek ik u dit aan het CBS door te geven, door deze brief te verbeteren en (eventueel apart van de vragenlijst) terug te zenden aan het CBS, Sector Waarneming Bedrijven Voorburg, Postbus 4000, 2270 JM Voorburg.

Retour zenden van de vragenlijst

Om de geheimhouding van de door u verstrekte gegevens te waarborgen kunt u de aanschrijfbrief met uw adresgegevens losscheuren. U hoeft alleen de vragenlijst te retourneren aan het CBS. **Ook als u niet alle vragen heeft kunnen beantwoorden, de vragenlijst a.u.b. retourneren.**

Inslagje afscheuren

Invulinstructie

Deze vragenlijst wordt geautomatiseerd verwerkt. Daarom is het belangrijk dat u:

- alle bedragen invult in duizenden euro. Dus bijvoorbeeld € 45 560,61 invullen als ☐☐☐☐ ☐4☐6 000,–
- de vragenlijst niet kreukt;
- de vragenlijst invult met zwarte of blauwe pen (géén rode pen en géén viltstift);
- duidelijk schrijft, zonder gebruik van komma's en/of punten;
- een duidelijk kruisje zet in het vak van uw keuze;
- de vakken op de juiste manier invult nl.:

☐6 is juist ingevuld ☐6 is niet juist ingevuld

- als per ongeluk het foute vakje is aangekruist, dan moet het goede vakje helemaal ingekleurd worden.

Centraal Bureau voor de Statistiek
Sector Waarneming Bedrijven Voorburg
Postbus 4000, 2270 JM Voorburg

Telefoon: (045) 570 64 00
Fax: (070) 337 59 93
E-mail: ldvtw@cbs.nl

RZ2234

ICT-gebruik bedrijven 2004

BE	SBI	GK	Sleutel

Gaarne terugzenden voor
in bijgevoegde portvrije retourenvelop.
Wilt u controleren of de code in het venster
zichtbaar is?

Onderwerp:
Deze enquête gaat over de automatisering en de toepassing van informatie- en communicatietechnologie (ICT) binnen uw bedrijf in 2004.
Dit varieert van kantoorautomatisering en andere vormen van automatisering t.b.v. administratie, planning en logistiek tot en met internetgebruik, elektronisch zakenverkeer (e-business/e-commerce), computerondersteund productontwerp en geautomatiseerde telefooncentrales.
NIET meetellen: fabrieks- en procesautomatisering.

1. Aantal werkzame personen

Totaal aantal werkzame personen van het bedrijf op 31 december 2004 ☐☐☐☐☐

Toelichting op de vragen

Ja of Nee vragen: aankruisen wat van toepassing is.

Bijvoorbeeld 254 als volgt noteren: ☐☐☐ 2 5 4

2. Computers

	Ja	Nee	
Gebruikte uw bedrijf eind 2004 computers?	☐	☐	Als Nee, ga naar vraag 14.
↳ zo Ja, welk percentage van de werkzame personen maakte bij het eigen werk regelmatig [1] gebruik van computers?	☐☐☐ %		Afronden op hele getallen. 32,1% als volgt noteren: ☐ 3 2 %

[1] Minimaal eens per week.

3. Automatiseringssystemen

	Ja	Nee	
Gebruikte uw bedrijf eind 2004 automatiseringssystemen voor het verwerken van inkoop- en/of verkooporders? [2]	☐	☐	Als Nee, ga naar vraag 4.
↳ zo Ja, was dit automatiseringssysteem (of systemen) automatisch gekoppeld [3] aan één of meer van de volgende automatiseringssystemen?			
Intern systeem voor voorraadbeheer	☐	☐	
Facturerings- en betalingssystemen	☐	☐	
Productie- en logistieke planningssystemen [4]	☐	☐	
Marketingsystemen [5]	☐	☐	
Bedrijfssystemen van toeleveranciers [6]	☐	☐	
Bedrijfssystemen van klanten (afnemers) [6]	☐	☐	

[2] Binnenkomende orders en/of door uw bedrijf geplaatste orders worden ter verdere afhandeling via een computer verwerkt.
[3] De gegevens van de ontvangen en/of geplaatste orders worden automatisch (zonder handmatige tussenkomst) verder verwerkt in één of meer van de genoemde systemen.
[4] Inclusief elektronische levering.
[5] Bijvoorbeeld het opbouwen van klantenbestanden voor mailings.
[6] Toeleveranciers en klanten/afnemers niet behorend tot uw eigen bedrijfconcern.

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4. Interne computernetwerken

Gebruikte uw bedrijf eind 2004:	Ja	Nee	
Een draadloos intern computernetwerk [7]	☐	☐	[7] *Local area network (LAN).*
Een vast intern computernetwerk [7]	☐	☐	
Intranet [8]	☐	☐	[8] *Een op Internettechnologie gebaseerd netwerk voor communicatie binnen uw bedrijf.*
Extranet [9]	☐	☐	[9] *Een beveiligde uitbreiding van het Intranet die derden toegang geeft tot (delen van) het Intranet van uw bedrijf.*

5. Internet

	Ja	Nee	
Gebruikte uw bedrijf eind 2004 Internet?	☐	☐	Als Nee, ga naar vraag 11.
➥ zo Ja, welk type verbinding werd hierbij gebruikt: [10]			[10] *Meerdan één antwoord mogelijk.*
Analoog modem (via de telefoon)	☐		
ISDN-verbinding	☐		
xDSL (ADSL, SDSL, e.d.)	☐		
Kabel	☐		
Andere hoogwaardige vaste verbinding [11]	☐		[11] *Waaronder vaste verbindingen met een grote bandbreedte zoals huur- en leaselijnen.*
Draadloze verbinding (satelliet, mobiele telefoon)	☐		[12] *Minimaal eens per week.*
Andere typen	☐		[13] *Computers met alleen toegang tot e-mail buiten beschouwing laten.*
Welk percentage van de werkzame personen maakte bij het eigen werk regelmatig [12] gebruik van computers met toegang tot Internet [13]?	☐☐☐ %		Afronden op hele getallen. 32,1% als volgt noteren: ☐3☐2 %
Welk percentage van de werkzame personen werkte in 2004 regelmatig [12] *buiten* uw bedrijfsvestiging EN had van daaruit wel toegang [14] tot het ICT-systeem van uw bedrijf?	☐☐☐ %	☐ geen	[14] *Alleen e-mail telt niet.*

6. Algemeen gebruik van Internet

Voor welke algemene doeleinden gebruikte uw bedrijf eind 2004 Internet?	Ja	Nee	
Financiële transacties [15]	☐	☐	[15] *Bijvoorbeeld online bankieren. Geen PIN-betaling.*
Training en opleiding [16]	☐	☐	[16] *Bijvoorbeeld e-learning.*
Marktmonitoring (bijv. prijzen) [17]	☐	☐	[17] *Zowel van mogelijke leveranciers (inkoopzijde) als van concurrenten op de eigen markt (verkoopzijde).*
Ontvangst bestelde producten/diensten [18]	☐	☐	
Klantondersteuning van toeleveranciers (after sales service)	☐	☐	[18] *Dit kan uiteraard alleen bij digitale producten zoals software, muziek, etc.*

7. Communicatie met overheden

	Ja	Nee	
Gebruikte uw bedrijf eind 2004 Internet om te communiceren met overheden? [19]	☐	☐	Als Nee, ga naar vraag 8.
➥ zo Ja, betrof dit het:			
Verkrijgen van informatie	☐	☐	
Verkrijgen ('downloaden') van formulieren	☐	☐	
Elektronisch retourneren van ingevulde formulieren [20]	☐	☐	
Volledig elektronische afhandeling van transacties [21]	☐	☐	

[19] Verkrijgen van informatie, 'downloaden' van formulieren etc.

[20] Elektronisch verzorgen van BTW-, LB, VPB- en andere belastingaangiftes. Ook elektronisch aanvragen bouwvergunning en subsidie meenemen.

[21] Bijvoorbeeld elektronische bezending parkeer- of bouwvergunning.

8. Internettoepassingen

Welke faciliteiten bood uw bedrijf eind 2004 aan via Internet?	Ja	Nee	
Presentatie eigen bedrijf via website	☐	☐	
Verstrekken van productinformatie [22]	☐	☐	
Verstrekken van prijsinformatie [22]	☐	☐	
'Eigen pagina' voor vaste klanten [23]	☐	☐	
Elektronisch afleveren van producten [24]	☐	☐	
Klantondersteuning aan afnemers (after sales service)	☐	☐	
Diensten geschikt voor mobiel Internet [25]	☐	☐	

[22] Van producten van uw eigen bedrijf.

[23] Zogenaamde 'customised page'.

[24] Dit kan uiteraard alleen bij digitale producten zoals software, muziek, etc.

[25] Diensten geschikt voor meer mobiele telefonie, maar ook voor andere vormen van draadloos Internet zoals een PDA en gebruikmakend van WAP of GPRS.

9. Verkopen via Internet

	Ja	Nee	
Heeft uw bedrijf in 2004 orders [26] ontvangen via Internet?	☐	☐	Als Nee, ga naar vraag 10.
➥ zo Ja, biedt uw bedrijf de mogelijkheid de bijbehorende betaling ook online te voldoen? [27]	☐	☐	
Heeft uw bedrijf in 2004 producten verkocht aan andere bedrijven via elektronische marktplaatsen? [28]	☐	☐	
Hoe groot was de omzet [29] gerealiseerd met orders ontvangen via Internet in 2004?			
– als absoluut bedrag (afronden op 1 000 euro):	☐☐☐☐☐☐ 000,–		Voorbeeld: € 73 640,– afronden als: ☐☐☐ 7 4 000,–
of:			
– in procenten van de totale omzet van uw bedrijf:	☐☐☐,☐ %		En 32,1% als volgt noteren: ☐ 3 2 , 1 %

[26] Inclusief elektronische boekingen en/of reserveringen. Exclusief handgetypte e-mails.

[27] Dit betekent dat de klant op het moment van bestellen tevens elektronisch de (machtiging tot) betaling verricht.

[28] Virtuele marktplaatsen voor bepaalde branches of producten. Deze kunnen zowel gesloten als algemeen toegankelijk zijn (zogenaamde e-markets).

[29] Een ruwe schatting volstaat eventueel.

9. Verkopen via internet (vervolg)

Omzet uit orders ontvangen via internet verdelen naar:

Regio afnemer:

In Nederland	☐☐☐ %	Afronden op hele getallen. 32,1% als volgt noteren: 32 %
In de overige EU-landen	☐☐☐ %	
Buiten de EU	☐☐☐ %	
	100 %	

Type afnemer:

Bedrijven/instellingen	☐☐☐ %
Overheid	☐☐☐ %
Huishoudens/consumenten	☐☐☐ %
	100 %

10. Inkopen via internet

	Ja	Nee	
Heeft uw bedrijf in 2004 via internet orders [30] geplaatst bij derden?	☐	☐	Als Nee, ga naar vraag 11.
➥ zo Ja, heeft uw bedrijf de bijbehorende betaling wel eens online voldaan? [31]	☐	☐	
Heeft uw bedrijf in 2004 orders geplaatst via elektronische marktplaatsen? [32]	☐	☐	

Voor welk bedrag [33] werden in 2004 door uw bedrijf orders geplaatst via internet?

- als absoluut bedrag (afronden op 1 000 euro): ☐☐☐☐☐ 000,– Voorbeeld: € 73 640,– afronden als: 74 000,–
- of:
- in procenten van de totale inkopen [34] van uw bedrijf: ☐☐☐,☐ % En 32,1% als volgt noteren: 32,1 %

30) Ook bijvoorbeeld het raadplegen van beheerde databanken.

31) Dit betekent dat uw bedrijf op het moment van bestellen tevens elektronisch de (machtiging tot) betaling verricht.

32) Virtuele marktplaatsen voor bepaalde branches of producten. Deze kunnen zowel gesloten als algemeen toegankelijk zijn (zogenaamde e-markets).

33) Een ruwe schatting volstaat eventueel.

34) Inkopen betekenen hier steeds alle door uw bedrijf in 2004 geplaatste orders.

11. In- en verkopen via andere elektronische netwerken

	Ja	Nee	
Gebruikte uw bedrijf in 2004 EDI of andere netwerken anders dan Internet?	☐	☐	Als Nee, ga naar vraag 12.
Gebruikte uw bedrijf deze netwerken voor het ontvangen van orders?	☐	☐	
➥ zo Ja, welk percentage van de totale omzet van uw bedrijf is in 2004 gerealiseerd met orders ontvangen via EDI of andere netwerken anders dan Internet?	☐☐☐,☐ %		92,1% als volgt noteren: ☐32,1 %
Gebruikte uw bedrijf deze netwerken voor het plaatsen van orders bij derden?	☐	☐	
➥ zo Ja, welk percentage van de totale inkopen van uw bedrijf bedroegen in 2004 de orders geplaatst via EDI of andere netwerken anders dan Internet?	☐☐☐,☐ %		

12. Beveiliging ICT-systemen

Gebruikte uw bedrijf eind 2004 één of meer van de volgende beveiligingsmaatregelen tegen 'digitale' dreiging van buitenaf?	Ja	Nee	
Antivirus of soortgelijke software	☐	☐	
Firewall	☐	☐	
Beveiligde webserver (secure server) [35]	☐	☐	
Off-site data back-up	☐	☐	
Gebruikte uw bedrijf bij elektronische communicatie met derden één of meer van de volgende beveiligingsmaatregelen?			
Digitale handtekening voor authenticatie klanten	☐	☐	
Andere authenticatiemiddelen (passwords, biometrie, e.d.)	☐	☐	
Data-encryptie ten behoeve van vertrouwelijkheid	☐	☐	
Is voor tenminste één van de met Ja aangekruiste beveiligingsmaatregelen een update [36] gemaakt in de laatste drie maanden?	☐	☐	
Heeft uw bedrijf de afgelopen 12 maanden veiligheidsproblemen gehad met de ICT-systemen?	☐	☐	
➥ zo Ja, betrof dit:			
Een virusaanval [37] resulterend in informatie- en/of tijdverlies	☐	☐	
Illegale toegang tot de ICT-systemen van uw bedrijf	☐	☐	
Chantage en/of bedreigingen m.b.t. de ICT-systemen van uw bedrijf [38]	☐	☐	
Andere veiligheidsproblemen	☐	☐	

35) *Servers gebruik makend van het secure-http-protocol. Te herkennen aan het adres beginnend met https.*

36) *Bijvoorbeeld het automatisch actualiseren van antivirussoftware.*

37) *Inclusief zaken als 'worms' en 'Trojan Horses'.*

38) *Bijvoorbeeld door het dreigen met beschadiging van software en/of data.*

CIS (innovation) Questionnaire

contactpersoon	Contact Center CBS
doorkiesnummer	(045) 570 64 00
correspondentienummer	
ons kenmerk	02230-04-S-BWV
onderwerp	Innovatie-enquête 2004
bijzonderheden	

Geachte heer/mevrouw,

Hierbij zend ik u de vragenlijst Innovatie-enquête 2004. Innovatie is de stuwende kracht achter economische vooruitgang en het verbeteren van de concurrentiepositie. Het gaat hierbij niet alleen om het vernieuwen van producten (goederen of diensten) en bedrijfsprocessen, maar ook om aanpassingen van de organisatie en marketingstrategieën. Het belang van innovatie wordt niet alleen onderkend door ondernemers. Ook de Nederlandse en Europese beleidsmakers hebben innovatie hoog op de agenda gezet en stimulering van innovatie tot een centrale doelstelling gemaakt.

Alle lidstaten van de Europese Unie zijn verplicht om aan de Europese Commissie gegevens te verstrekken over innovatie van bedrijven in hun land (Verordening EC 1450/2004). Daartoe is een Europees geharmoniseerde vragenlijst opgesteld, waarvan de Nederlandse versie nu voor u ligt. In deze enquête wordt informatie verzameld over product- en procesinnovatie en organisatorische- en marketinginnovatie in de periode 2002/2004.
Om bedrijven met en zonder innovatie-activiteiten te kunnen vergelijken, vragen we aan alle bedrijven om alle vragen te beantwoorden, tenzij anders aangegeven.

Actualiteit van de genoemde gegevens is van groot belang. Ik verzoek u de aangehechte vragenlijst vóór de daarop vermelde terugzenddatum, ingevuld te retourneren. Hierbij kunt u gebruik maken van bijgevoegde retourenvelop.

Uitkomsten van deze en andere enquêtes kunt u bekijken via de CBS-website: www.cbs.nl.

Als u naar aanleiding van deze enquête vragen heeft, kunt u contact opnemen met één van de medewerkers van bovengenoemd Contact Center.

Voor uw medewerking dank ik u bij voorbaat.

Hoogachtend,
Hoofd Sector Waarneming Bedrijven Voorburg

Drs. R.H.M. Smulders

CBS Voorburg

Prinses Beatrixlaan 428
Postbus 4000
2270 JM Voorburg

Adreswijziging

Indien de tenaamstelling en/of adressering niet correct is, verzoek ik u dit aan het CBS door te geven, door deze brief te verbeteren en (eventueel apart van de vragenlijst) terug te zenden aan het CBS, Sector Waarneming Bedrijven Voorburg, Postbus 4000, 2270 JM Voorburg.

Retour zenden van de vragenlijst

Om de geheimhouding van de door u verstrekte gegevens te waarborgen kunt u de aanschrijfbrief met uw adresgegevens loscheuren. U hoeft alleen de vragenlijst te retourneren aan het CBS. **Ook als u niet alle vragen heeft kunnen beantwoorden, de vragenlijst a.u.b. retourneren.**

Ga door ➡

Invulinstructie

Deze vragenlijst wordt geautomatiseerd verwerkt. Daarom is het belangrijk dat u:

– alle bedragen invult in duizendtallen euro. Dus bijvoorbeeld € 45 560,61 invullen als ☐☐☐☐46 000,–

– de vragenlijst niet kreukt;

– de vragenlijst invult met **zwarte** of **blauwe** pen (**géén** rode pen en **géén** viltstift);

– duidelijk schrijft, zonder gebruik van komma's en/of punten;

– een duidelijk kruisje zet in het vak van uw keuze;

– de vakken op de juiste manier invult n.l.:

☒ is juist ingevuld ☐ is niet juist ingevuld

– als per ongeluk het foute vakje is aangekruist, dan moet het goede vakje helemaal ingekleurd worden.

Centraal Bureau voor de Statistiek
Sector Waarneming Bedrijven Voorburg
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RZ2222

Innovatie-enquête 2004

BE	SBI	GK	Sleutel



Gaarne terugzenden voor
in bijgevoegde portvrije retourenvelop.
Wilt u controleren of de code in het venster
zichtbaar is?

In deze enquête wordt informatie verzameld over vernieuwingen bij bedrijven in de periode van 2002 tot en met 2004. De meeste vragen hebben betrekking op nieuwe of sterk verbeterde goederen of diensten of de toepassing van nieuwe of sterk verbeterde processen, logistieke of distributiemethoden. Organisatorische en marketinginnovaties komen nadrukkelijk in een aparte vraag aan bod.
U wordt verzocht om alle vragen te beantwoorden, tenzij anders aangegeven.

1. Algemene informatie over het bedrijf

	Ja	Nee
1.1 Is uw bedrijf onderdeel van een concern (groep van bedrijven)?	☐	☐

Een concern bestaat uit twee of meer wettelijk omschreven bedrijven in gemeenschappelijk eigendom. Elk bedrijf in het concern kan verschillende geografische markten bedienen, zoals in het geval van nationale of regionale dochtermaatschappijen, of verschillende productmarkten. Het hoofdkantoor is ook onderdeel van het concern.

↓
In welk land is het hoofdkantoor van het concern gevestigd?

Als uw bedrijf deel uitmaakt van een concern, gelieve u de volgende vragen alleen voor uw bedrijf in Nederland te beantwoorden. Voeg geen resultaten voor dochter- of moedermaatschappijen buiten Nederland toe.

1.2 In welke geografische markten verkocht uw bedrijf goederen of diensten in de periode 2002–2004?	Ja	Nee
Lokaal/regionaal binnen Nederland.	☐	☐
Heel Nederland.	☐	☐
Andere, specifiek genoemde, Europese landen [1].	☐	☐
Overige landen.	☐	☐

[1] Het betreft de volgende EU- en kandidaat EU-landen, alsmede de landen van de EVA:
België, Bulgarije, Cyprus, Denemarken, Duitsland, Estland, Finland, Frankrijk, Griekenland, Hongarije, Ierland, Italië, Kroatië, Letland, Liechtenstein, Litouwen, Luxemburg, Malta, Noorwegen, Oostenrijk, Polen, Portugal, Roemenië, Slovenië, Slowakije, Spanje, Tsjechië, Turkije, Verenigd Koninkrijk, IJsland, Zweden en Zwitserland.

2. Productinnovatie (goederen of diensten)

➥ Een productinnovatie is de marktintroductie van **nieuwe** of **sterk verbeterde** goederen of diensten wat betreft de toepassingsmogelijkheden. Bijvoorbeeld nieuwe of verbeterde software, gebruiksvriendelijkheid, componenten of subsystemen. De innovatie (vernieuwing of verbetering) moet nieuw zijn voor uw bedrijf, maar hoeft dat niet voor uw bedrijfstak of markt te zijn. Het maakt niet uit of de innovatie oorspronkelijk door uw bedrijf of door andere bedrijven (denk ook aan afnemers en leveranciers) is ontwikkeld.

2.1 Heeft uw bedrijf in de periode 2002–2004 geïntroduceerd:

	Ja	Nee
Goederen die voor úw bedrijf nieuw of sterk verbeterd zijn Niet meetellen: het doorverkopen van nieuwe goederen die bij een ander bedrijf zijn ingekocht en goederen die alleen esthetische veranderingen hebben ondergaan.	☐	☐
Diensten die voor úw bedrijf nieuw of sterk verbeterd zijn	☐	☐

➥ 2 x **Nee**, ga naar 3.

2.2 Wie heeft deze productinnovaties ontwikkeld?

Voornamelijk uw bedrijf of andere bedrijven binnen uw concern.	☐
Uw bedrijf samen met andere bedrijven of instellingen.	☐
Voornamelijk andere bedrijven of instellingen.	☐

Kies het antwoord dat het meest van toepassing is.

2.3 Waren deze productinnovaties (goederen en diensten) in de periode 2002–2004:

		Ja	Nee
Nieuw voor uw markt?	Uw bedrijf heeft eerder dan de concurrenten nieuwe of sterk verbeterde goederen of diensten op uw markt gebracht (ook al waren deze misschien al op andere markten beschikbaar).	☐	☐
Alleen nieuw voor uw bedrijf?	Uw bedrijf heeft nieuwe of sterk verbeterde goederen of diensten geïntroduceerd die al eerder door concurrenten op uw markt waren gebracht.	☐	☐

2.4 Hoeveel bedroeg, in % van uw totale omzet [2] in 2004, het aandeel van elk van deze groepen:

		2004 omzetverdeling
Nieuw voor uw markt?	In 2002–2004 geïntroduceerde goederen- en diensteninnovaties die **nieuw voor uw markt** waren.	☐☐☐ %
Alleen nieuw voor uw bedrijf?	In 2002–2004 geïntroduceerde goederen- en diensteninnovaties die **alleen nieuw voor uw bedrijf** waren.	☐☐☐ %
Onveranderd of slechts licht veranderd?	Goederen en diensten die in 2002–2004 **niet of nauwelijks zijn veranderd** (inclusief doorverkoop van nieuwe goederen of diensten die van andere ondernemingen zijn ingekocht).	☐☐☐ %
	Totale omzet in 2004	\+ 1 0 0 %

[2] Voor kredietinstellingen: rente en soortgelijke baten; voor verzekeraars: geboekte brutopremies.

3. Procesinnovatie

➥ Procesinnovatie is de toepassing van een **nieuw of sterk verbeterd** productieproces, distributiemethode of ondersteunende activiteit voor uw goederen of diensten. De innovatie (vernieuwing of verbetering) moet nieuw zijn voor uw bedrijf, maar hoeft dat niet te zijn voor uw bedrijfstak of markt. Het maakt niet uit of de innovatie oorspronkelijk door uw bedrijf of door andere bedrijven (denk ook aan afnemers en leveranciers) is ontwikkeld. Puur organisatorische innovaties vallen hier niet onder.

3.1 Heeft uw bedrijf in de periode 2002–2004 nieuwe of sterk verbeterde methoden in gebruik genomen:

	Ja	Nee
Voor de productie van goederen of diensten.	☐	☐
Voor de logistiek (levering of distributie) van uw inputs (goederen of diensten).	☐	☐
Voor ondersteunende activiteiten voor uw processen, zoals onderhoudssystemen of aankoop-, boekhoudkundige of calculatiemethoden.	☐	☐

➥ 3 x **Nee**, ga naar 4.

3.2 Wie heeft deze procesinnovaties ontwikkeld?

Voornamelijk uw bedrijf of andere bedrijven binnen uw concern. ☐

Uw bedrijf samen met andere bedrijven of instellingen. ☐

Voornamelijk andere bedrijven of instellingen. ☐

Kies het antwoord dat het meest van toepassing is.

4. Lopende of afgebroken innovatie-activiteiten

➥ Onder innovatie-activiteiten wordt verstaan: de aanschaf van machines, apparatuur, software en licenties; nieuwbouw en ontwikkeling, opleiding, marketing en R&D, als deze **specifiek gericht** waren op de ontwikkeling en/of implementatie van een product- of procesinnovatie.

4.1 Heeft uw bedrijf innovatie-activiteiten verricht voor het ontwikkelen en implementeren van product- of procesinnovaties die in de periode 2002–2004 zijn *afgebroken* of die eind 2004 *nog niet waren afgerond*?

Ja	Nee
☐	☐

➥ indien u bovendien bij 2.1 én bij 3.1 steeds **NEE** antwoordde (m.a.w. *géén* proces- én *géén* productinnovatie heeft geïntroduceerd)
GAAT U NU DIRECT NAAR 8.2.

Ga in andere gevallen verder naar 5.1.

5. Innovatie-activiteiten en -uitgaven

5.1 Heeft uw bedrijf in de periode 2002–2004 de volgende innovatie-activiteiten verricht:

		Ja	Nee
Eigen R&D (onderzoek met eigen personeel) Creatieve werkzaamheden binnen uw bedrijf om kennis te vergroten of toe te passen bij het ontwerpen van nieuwe en verbeterde producten en processen (inclusief de ontwikkeling van software).	1	☐	☐
➥ Zo Ja, hoe regelmatig vond de R&D bij uw bedrijf in de periode 2002–2004 plaats?		☐ doorlopend ☐ incidenteel	
Uitbestede R&D Dezelfde activiteiten als hierboven, maar verricht door andere bedrijven (waaronder andere bedrijven binnen uw concern) of door publieke of particuliere onderzoeksorganisaties en aangekocht door uw onderneming.	2	☐	☐
Aankoop van machines, apparatuur en software Aankoop van geavanceerde machines, apparatuur en computerhard-ware of -software ten behoeve van nieuwe of sterk verbeterde producten en processen.	3	☐	☐
Aankoop van andere externe kennis Aankoop van of licentieovereenkomsten voor octrooien en niet-gepatenteerde uitvindingen, knowhow en andere vormen van kennis van andere bedrijven of organisaties.	4	☐	☐

	Ja	Nee
Opleiding Interne of externe opleidingen voor uw personeel specifiek gericht op de ontwikkeling en/of introductie van nieuwe of sterk verbeterde producten en processen.	☐	☐
Marktintroductie van innovaties Activiteiten voor de marktintroductie van nieuwe of sterk verbeterde goederen en diensten, inclusief marktonderzoek en reclame bij de productintroductie.	☐	☐
Andere voorbereidingen Procedures en technische voorbereidingen voor de implementatie van nieuwe of sterk verbeterde producten en processen die niet in een van de eerder genoemde categorieën vallen.	☐	☐

➥ Zo Ja, vermeld bij 5.2 uitgaven gedaan in 2004.

5.2 Geef een schatting van de uitgaven in 2004 voor de eerste vier (1 t/m 4) innovatieactiviteiten zoals genoemd in vraag 5.1.

		Kruis aan indien nihil
Eigen R&D (onderzoek met eigen personeel) Bruto loon van R&D-personeel, bijkomende kosten van bijv. reiskosten, laboratoria, documentatie en computertijd, investeringen in gebouwen en apparatuur voor R&D.	1	☐☐☐☐☐☐ 000,– ☐
Uitbestede R&D Kosten van R&D uitbesteed binnen het concern of aan andere ondernemingen, universiteiten, researchinstellingen (zoals TNO) in Nederland of in het buitenland.	2	☐☐☐☐☐☐ 000,– ☐
Aankoop van machines, apparatuur en software Voor zover niet begrepen in uitgaven voor apparatuur voor R&D.	3	☐☐☐☐☐☐ 000,– ☐
Aankoop van andere externe kennis	4	☐☐☐☐☐☐ 000,– ☐
Totaal van deze vier uitgavencategorieën (1 t/m 4) voor innovatie		+ ☐☐☐☐☐☐ 000,– ☐

5. Innovatie-activiteiten en -uitgaven (vervolg)

Ga direct naar vraag 5.4 indien uw bedrijf zelf geen R&D-werkzaamheden heeft uitgevoerd.

5.3 Hoeveel medewerkers van uw bedrijf, in aantal en in arbeidsjaren [3], hebben in 2004 werkzaamheden verricht in het kader van R&D?

		Aantal medewerkers eind 2004	Arbeidsjaren in 2004
Onderzoekers	Wetenschappelijk opgeleide personen betrokken bij het onderzoek, inclusief de leidinggevenden in dat onderzoek.	☐☐☐☐	☐☐☐☐,☐
Assistenten	Assistenten, op hoog niveau meewerkend met en onder supervisie van de onderzoekers.	☐☐☐☐	☐☐☐☐,☐
Overig personeel	Onderhouds-, secretariaats-, bibliotheek- en/of kantoorpersoneel direct werkend voor de R&D in uw bedrijf.	☐☐☐☐	☐☐☐☐,☐ +
			☐☐☐☐,☐ A
Prognose 2005	Hoeveel arbeidsjaren (als bij **A**) verwacht u in 2005 voor R&D in te zetten?		☐☐☐☐,☐

5.4 Heeft uw bedrijf in de periode 2002–2004 overheidssteun voor innovatie-activiteiten ontvangen?

Deze vraag betreft ook financiële steun in de vorm van belastingfaciliteiten, subsidies, gesubsidieerde leningen en garanties voor leningen.
De vraag heeft geen betrekking op onderzoek en andere innovatie-activiteiten die volgens contract volledig voor de overheid zijn verricht.

	Ja	Nee
Lokale of regionale overheden	☐	☐
Nationale overheid (inclusief agentschappen of ministeries)	☐	☐
Europese Unie (EU)	☐	☐
Heeft uw bedrijf deelgenomen aan het vijfde (1998–2002) of zesde (2003–2006) kaderprogramma voor onderzoek en technologische ontwikkeling van de EU?	☐	☐

[3] Als één arbeidsjaar telt een voltijdsmedewerker die alle werktijd besteedt aan R&D. Een deeltijdbaan of iemand die niet alle werktijd besteedt aan R&D slechts meetellen voor een gedeelte van een arbeidsjaar. Bijvoorbeeld : een medewerker die twee dagen per week besteedt aan R&D telt voor 2/5 (0,4) arbeidsjaar.

6. Informatiebronnen en samenwerking

6.1 Hoe belangrijk waren de volgende informatiebronnen in de periode 2002–2004 voor de innovatie-activiteiten van uw bedrijf?

(Geef aan welke bronnen informatie verschaften voor nieuwe innovatie-projecten of bijdroegen aan de uitvoering van bestaande innovatieprojecten.)

	Bron is gebruikt en was:			*Niet gebruikt*
	Zeer belangrijk	**Belangrijk**	**Enigszins belangrijk**	
Interne bronnen				
Binnen uw bedrijf of andere bedrijven binnen uw concern	☐	☐	☐	☐
Commerciële (markt-) bronnen				
Leveranciers van apparatuur, materialen, componenten of software	☐	☐	☐	☐
Afnemers	☐	☐	☐	☐
Concurrenten of andere bedrijven in uw bedrijfstak	☐	☐	☐	☐
Consultants, commerciële laboratoria of particuliere R&D-instituten	☐	☐	☐	☐
Institutionele bronnen				
Universiteiten of andere instellingen voor hoger onderwijs	☐	☐	☐	☐
Overheids- of openbare onderzoeksinstellingen	☐	☐	☐	☐
Overige bronnen				
Conferenties, beurzen of exposities	☐	☐	☐	☐
Wetenschappelijke tijdschriften en vak-/technische publicaties	☐	☐	☐	☐
Beroeps- en brancheverenigingen	☐	☐	☐	☐

6.2 Heeft uw bedrijf in de periode 2002–2004 bij innovatie-activiteiten samengewerkt met andere bedrijven of instellingen?

Dit is het actief samenwerken met andere bedrijven of niet-commerciële instellingen op het gebied van innovatie-activiteiten. De partners hebben niet noodzakelijk beide commercieel baat bij de samenwerking. Deze vraag heeft geen betrekking op uitbesteding van werkzaamheden zonder actieve samenwerking.)

Ja	**Nee**
☐	☐

➥ Indien Nee ga naar 7.1.

	Partner gevestigd in			
	Nederland	**Ander Europees land**[4]	**Verenigde Staten**	**Overige landen**
A Andere bedrijven binnen uw concern	☐	☐	☐	☐
B Leveranciers van apparatuur, materialen, componenten of software	☐	☐	☐	☐
C Afnemers	☐	☐	☐	☐
D Concurrenten of andere bedrijven in uw bedrijfstak	☐	☐	☐	☐
E Consultants, commerciële laboratoria of particuliere R&D-instituten	☐	☐	☐	☐
F Universiteiten of andere instellingen voor hoger onderwijs	☐	☐	☐	☐
G Overheids- of openbare onderzoeksinstellingen	☐	☐	☐	☐

6.3 Welk van deze samenwerkingspartners (A–G) vond u het meest waardevol voor de innovatie-activiteiten van uw bedrijf?

Kruis één vakje aan

A	**B**	**C**	**D**	**E**	**F**	**G**
☐	☐	☐	☐	☐	☐	☐

[4] Het betreft de volgende EU- en kandidaat EU-landen, alsmede de landen van de EVA:
België, Bulgarije, Cyprus, Denemarken, Duitsland, Estland, Finland, Frankrijk, Griekenland, Hongarije, Ierland, Italië, Kroatië, Letland, Liechtenstein, Litouwen, Luxemburg, Malta, Noorwegen, Oostenrijk, Polen, Portugal, Roemenië, Slovenië, Slowakije, Spanje, Tsjechië, Turkije, Verenigd Koninkrijk, IJsland, Zweden en Zwitserland.

7. Effecten van innovatie

7.1 Hoe belangrijk waren de volgende effecten van de innovatie van producten (goederen of diensten) of processen die in de periode 2002–2004 zijn geïntroduceerd?	*Effect is waargenomen en was:* Sterk	Gematigd	Zwak	*Niet waargenomen*
Productgerichte effecten				
Breder assortiment van goederen of diensten	☐	☐	☐	☐
Nieuwe markten of groter marktaandeel	☐	☐	☐	☐
Betere kwaliteit van goederen of diensten	☐	☐	☐	☐
Procesgerichte effecten				
Meer flexibiliteit in productie of dienstverlening	☐	☐	☐	☐
Grotere productie- of dienstverleningscapaciteit	☐	☐	☐	☐
Lagere loonkosten per eenheid output	☐	☐	☐	☐
Minder materiaal- en energieverbruik per eenheid output	☐	☐	☐	☐
Overige effecten				
Minder milieubelasting of betere gezondheid en veiligheid	☐	☐	☐	☐
Naleving van regelgeving	☐	☐	☐	☐

8. Belemmeringen

8.1 Ondervond uw bedrijf in de periode 2002–2004 belemmeringen waardoor innovatie-activiteiten of -projecten:	Ja	Nee
Zijn afgebroken in het conceptstadium.	☐	☐
Zijn afgebroken na het begin van de activiteit of het project.	☐	☐
Ernstig zijn vertraagd.	☐	☐

! 8.2 In welke mate hebben in de periode 2002–2004 de volgende factoren een belemmering gevormd voor uw innovatie-activiteiten of -projecten of hebben zij de beslissing om niet te innoveren beïnvloed?	*Belemmering is waargenomen en was:* Sterk belemmerend	Belemmerend	Zwak belemmerend	*Niet waargenomen*
Kostenfactoren				
Gebrek aan financiële middelen in bedrijf of concern	☐	☐	☐	☐
Gebrek aan externe financiële middelen	☐	☐	☐	☐
Te hoge innovatiekosten	☐	☐	☐	☐
Kennisfactoren				
Gebrek aan gekwalificeerd personeel	☐	☐	☐	☐
Gebrek aan informatie over technologie	☐	☐	☐	☐
Gebrek aan marktinformatie	☐	☐	☐	☐
Moeite met het vinden van samenwerkingspartners voor innovatie	☐	☐	☐	☐
Marktfactoren				
Markt gedomineerd door gevestigde ondernemingen	☐	☐	☐	☐
Andere factoren				
Onzekere vraag naar innovatieve goederen of diensten	☐	☐	☐	☐
Door eerdere innovaties geen noodzaak tot nieuwe innovaties	☐	☐	☐	☐
Geen behoefte aan/ belang bij (eigen) innovaties	☐	☐	☐	☐

9. Intellectuele-eigendomsrechten

9.1 Heeft uw bedrijf in de periode 2002–2004:	Ja	Nee
Een octrooi aangevraagd.	☐	☐
Een industrieel ontwerp gedeponeerd.	☐	☐
Een handelsmerk gedeponeerd.	☐	☐
Een auteursrecht vastgelegd.	☐	☐

10. Organisatorische en marketinginnovaties

➥ Een organisatorische innovatie is een vernieuwing van of een ingrijpende verandering in de bedrijfsstructuur of managementmethoden met als doel de benutting van kennis en daardoor de efficiency van het bedrijfsproces en/of de de kwaliteit van uw goederen en diensten te verbeteren.

➥ Een marketinginnovatie is de implementatie van nieuwe of sterk verbeterde produktontwerpen/ -uitvoeringen of verkoopmethoden om uw goederen en diensten aantrekkelijker te maken of om nieuwe markten te veroveren.

10.1 Heeft uw bedrijf in de periode 2002–2004 de volgende innovaties geïntroduceerd:

		Ja	Nee
Organisatorische innovaties	Nieuwe of sterk verbeterde kennismanagement-systemen om informatie, kennis en vaardigheden binnen uw bedrijf beter te benutten.	☐	☐
	Een grote verandering in de organisatie van uw bedrijf, zoals veranderingen in de management-structuur of de samenvoeging van verschillende afdelingen of activiteiten.	☐	☐
	Nieuwe of ingrijpende veranderingen in uw relaties met andere bedrijven of instellingen, bijvoorbeeld via samenwerkingsverbanden, uitbesteding of onderaanbesteding.	☐	☐
Marketing innovaties	Ingrijpende veranderingen in het produktontwerp of de verpakking van goederen of diensten, anders dan gebruikelijke (seizoens)veranderingen zoals in de mode.	☐	☐
	Nieuwe of ingrijpend veranderde verkoop- of distributiemethoden, zoals internetverkoop, franchising, rechtstreekse verkoop of distributie-licenties.	☐	☐

➥ Indien Ja: geef in 10.2 het effect aan

10.2 Als 'Organisatorische innovaties' zijn geïntroduceerd, hoe belangrijk waren de volgende effecten in de periode 2002–2004

	Effect is waargenomen en was:			*Niet waar-genomen*
	Sterk	Gematigd	Zwak	
Snellere reactie op vragen van klanten of leveranciers.	☐	☐	☐	☐
Betere kwaliteit van goederen of diensten .	☐	☐	☐	☐
Lagere kosten per eenheid output.	☐	☐	☐	☐
Meer werkplezier bij uw medewerkers en/of minder personeelsverloop.	☐	☐	☐	☐

11. Economische basisgegevens van uw bedrijf

11.1 Hoeveel bedroeg de totale omzet [5] van uw bedrijf in 2002 resp. in 2004?

Omzet wordt gedefinieerd als de marktwaarde van goederen en diensten exclusief BTW, doch inclusief alle overige belastingen. Vermeld het bedrag in duizenden euro.

2002

□□□ □□□ □□□ 000,–

2004

□□□ □□□ □□□ 000,–

11.2 Hoeveel werknemers had uw bedrijf in 2002 resp. in 2004 in dienst?

Vermeld het jaargemiddelde. Als dat niet beschikbaar is, dan graag het aantal werknemers per ultimo opgeven.

2002

□□□ □□□

2004

□□□ □□□

[5] Voor kredietinstellingen: rente en soortgelijke baten; voor verzekeraars: geboekte brutopremies.

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