From Broadband to Organizational Productivity

Steven Ngabonziza Rugemintwaza

August 21, 2009

Master of Science Thesis

Student Number: 1385054

TU Delft

Delft University of Technology

From Broadband to Organizational Productivity

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

ELECTRICAL ENGINEERING

by

Steven Ngabonziza Rugemintwaza

Committee Members:

Supervisor:	Prof. N.H.G. Baken (TU Delft-NAS/KPN)
Mentor:	Ir. A.J.P.S. Madureira (TU Delft-NAS)
Examiners:	Ing. E.F.M. van Boven (TU Delft-NAS/KPN)
	Dr. ir. A. Lo (TU Delft-WMC)
	Dr. ir. R. Hekmat (TU Delft-WMC/Cap Gemini)

Network Architectures and Services (NAS) Group
Faculty of Electrical Engineering, Mathematics & Computer Science
Delft University of Technology

Delft University of Technology

Dedicated to the memory of

Vénuste Rugemintwaza

and

Françoise Mwiteneza

Abstract

Broadband infrastructures are advanced telecommunication systems capable of providing high-speed transmission of services. Broadband deployment has the potential to bring valuable new services, stimulate economic activity, advance economic opportunity and improve productivity. For example, the European Commission has stated that "widespread and affordable broadband access is essential to realize the potential of the information society". Despite this general perception, the announced impacts were not yet backed up with factual evidence. Scientifically grounding this perception is an essential input to the development of telecommunication infrastructures related public and private policies. This thesis contributes to clarify the importance of broadband, by investigating the following research questions: 1) what is the state of the art concerning the impact of broadband to organizational productivity; 2) is there any thorough and generally accepted framework to investigate the relation from broadband to organizational productivity; 3) if not, which framework can be used; 4) how can the applicability of such framework be tested; and 5) which conclusions can be derived about the impact of broadband using this framework. The methodology used to investigate these research questions is based on literature reviews and a survey. From a general observation of the results of the survey, it can be concluded that the majority of the interviewees are conscientious of the impact of the digital information networks and broadband on their productivity, but are not able to distinguish broadband from narrowband. In general, they don't care about the types of networks they are using as long as they can do their job. At this stage, no concrete conclusion can be drawn about the impact of broadband, since users are not clarified about the difference between broadband and narrowband networks. Although the relevance of broadband was validated with a literature review, there is a lack of confirmation of the perceived impacts with an empirical validation. A careful re-design of the questions of the questionnaire should be able to clarify to the target population the difference between these two networks. From a scientific perspective, the novelty of this work lies on the application of a novel framework useful to structure the outcomes of broadband impact studies in a valid conceptual way. From an applied perspective, this work can contribute to clarify utopian and opposite dystopian views of broadband, particularly aiming policy makers and organizational managers.

Acknowledgements

I would like to take this opportunity to thank all the people who contributed directly or indirectly for the success of my Master's study at Delft University of Technology, including those whose names are not mentioned below.

First and foremost I would like to express my gratitude to my sponsor, the African Bank Development (ADB) Group, who gave me the opportunity to do this Master's program.

I am grateful to my mentor, Antonio Madureira, for his guidance and help throughout the work. Antonio, your valuable critical comments and remarks were always important. I am grateful to my supervisor, Prof. Nico Baken, who gave me the opportunity to do my research in the Trans-sector Innovation team. I also thank Edgar van Boven, for taking time to read and to comment on my draft thesis.

I would like to thank the Executive Director of RITA, Nkubito Bakurambutsa, for his willingness to approve my study leave from work. Thanks to the human resource officer, Teta Nadine, for her cooperation and kindness in providing me with all the necessary information and documents.

I acknowledge the contributions of all my friends here in Delft who helped me (Leopold, Marcel, Marcellin, Chloe, Xavier, and Sylvère) and classmates who endured this long process with me, always offering support and love (Dony, Aman, Nasir, Carolyn, Vijay, Shahzad, Mohamed and Deborah).

My warmest thanks to uncle Julien Kaburame and his wife Lea Nyinawumwami, for the incredible support in taking care of my family during my absence. Kaburame, thank you so much for taking my son to school for the whole period I was absent. Lea, thank you for taking care of my wife and our new baby to maternity and after. Thanks to my brother Bizimana, untie Monique and her family, for all their support and help brought to my family during my absence.

Finally and most important, I would like to express my deepest gratitude and love to my wife Yvette Mpozenzi and my son Miguel S. Ngabonziza, who have been a catalyst for my hard work, and my daughter Chloe M. Kaburame, who blessed my family during my absence. Yvette, thank you for your wonderful love, patience and full support.

Last but not the least, I give glory and honour to God, who has helped me through out my life, and blessed me to complete this Master's program. My achievements would not have been possible without His love.

Steven Ngabonziza
Delft, The Netherlands
August 21, 2009

Contents

Abstract iii

Acknowledgements v

Acronyms ix

1 Introduction 1
- 1.1 What is broadband? . . . 2
- 1.2 Broadband potential . . . 2
- 1.3 Motivation . . . 4
- 1.4 Research questions . . . 5
- 1.5 Contribution . . . 5
- 1.6 Organization of the thesis document . . . 6

2 State of the Art and Research Challenges 7
- 2.1 State of the art . . . 7
- 2.2 Research challenges . . . 11
  - 2.2.1 Causality . . . 11
  - 2.2.2 Separability . . . 11
  - 2.2.3 Externality . . . 12
  - 2.2.4 Endogeneity . . . 12
  - 2.2.5 Availability . . . 12
- 2.3 Discussion and conclusion . . . 13

3 Theoretical Background- the Trans Model 15
- 3.1 Introduction . . . 15
- 3.2 Capabilities . . . 16
- 3.3 Sensitivity . . . 17
- 3.4 Trustability . . . 17
- 3.5 Normativity . . . 18
- 3.6 Hierarchity . . . 18
- 3.7 Coordinativity . . . 19
- 3.8 Cooperativity . . . 19
- 3.9 Selectivity . . . 20
- 3.10 Negotiability . . . 20
- 3.11 Adoptativity . . . 20
- 3.12 Creativity . . . 21

3.13 Discussion and conclusion 23

4 From Broadband to Productivity- with the Trans Model 25
4.1 Sensitivity 25
4.2 Trustability 25
4.3 Normativity 26
4.4 Hierarchity 26
4.5 Coordinativity 27
4.6 Cooperativity 27
4.7 Selectivity 28
4.8 Negotiability 28
4.9 Adoptativity 28
4.10 Creativity 29
4.11 Discussion and conclusion 29

5 Questionnaire Development and Test 31
5.1 Survey design 31
5.1.1 Goals and cover letter 31
5.1.2 Delivery methods 32
5.1.3 Questions 34
5.2 Survey test 42
5.3 Results of the survey test 43
5.3.1 Sensitivity 43
5.3.2 Trustability 44
5.3.3 Normativity 44
5.3.4 Hierarchity 45
5.3.5 Coordinativity 46
5.3.6 Cooperativity 47
5.3.7 Selectivity 47
5.3.8 Negotiability 48
5.3.9 Adoptativity 48
5.3.10 Creativity 49
5.4 Discussion and conclusion 51

6 Conclusion and future work 55
6.1 Conclusion 55
6.2 Future work 57

Bibliography 59

Appendices 69

A Cover letter 69

B Survey's questions 71

Acronyms

ACG: Allen Consulting Group

ADB: African Bank Development

ADSL: Asymmetric Digital Subscriber Line

AGE: Applied General Equilibrium

BCC: British Chambers of Commerce

BSG: Broadband Stakeholder Group

CBS: Centraal Bureau voor de Statistiek

CBTF: California Broadband Task Force

CEBR: Centre for Economics and Business Research

CEO: Chief Executive Officer

DINs: Digital Information Networks

DSL: Digital Subscriber Line

DTI: Department of Trade and Industry

EU: European Union

FCC: Federal Communications Commission

ICT: Information and Communication Technology

IO: Input-Output

ISDN: Integrated Services Digital Network

IT: Information Technology

NTIA: National Telecommunications and Information Administration

OECD: Organisation for Economic Co-operation and Development

RITA: Rwanda Information Technology Authority

SNG: Strategic Networks Group

TA: Technology Administration

TV: Television

UK: United Kingdom

UMTS: Universal Mobile Telecommunications System

US: United States

VoD: Video-on-Demand

Chapter 1

Introduction

Broadband networks are advanced telecommunication systems capable of providing high-speed transmission of services, and are largely used by organizations and individuals. They have become an indispensable support for information flows between organizations, and enable individuals to have access to a very large quantity of information and services at home or at work. Broadband deployment has the potential to bring valuable new services, stimulate economic activity, advance economic opportunity and improve productivity. For example, the European Commission has stated that "widespread and affordable broadband access is essential to realize the potential of the information society".

However, there are many challenges in the process of finding empirical evidences of the economic value of broadband. This analysis confronts the same type of challenges that led to the productivity paradox of Information Technology (IT), best articulated by the economist Robert Solow: "we see computers everywhere except in the productivity statistics". Although there is a significant number of studies on the economic impact of broadband infrastructures, in general these studies tend to be more rhetoric, lacking specific and empirical grounding for their claims, simply relying on analysis and correlation of data, and not explaining thoroughly why these correlations should exist. Hence, it seems that these studies are hampered by an insufficient theoretical base.

This thesis contributes to clarify the economic importance of broadband to organizational productivity. From a scientific perspective, this work investigates the application of a novel framework useful to structure the outcomes of broadband impact studies in a valid conceptual way. The applicability of this framework was tested with a literature review. Furthermore, a questionnaire was done based on this framework. Based on this questionnaire, a survey was done to a relevant population to test the clarity of the questionnaire, to test the completeness of the framework used and to get a preliminary impression on the impact of broadband to organizational productivity. From a general observation taken from the results of this work, the majority of interviewees are conscientious of the impact of the digital information networks and broadband on their productivity, but are not able to distinguish broadband from narrowband. In general, they don't care about the types of networks they are using as long as they can do their job. From the practical perspective, this work can be used by policy makers to justify the value of broadband and investments in more advanced forms of infrastructure, and by organizational

managers aiming at higher productivity gains.

1.1 What is broadband?

There are diverse definitions of 'broadband'. A possible one was suggested by the U.S. Federal Communications Commission (FCC) that defines broadband as: *"advanced telecommunication systems capable of providing high-speed transmission of services such as data, voice, and video over the internet and other networks"*. This definition has less to do with the technical speed and instead focuses on functionality, which has more to do with what a user can do with broadband (see [Sawyer et al., 2003]). Omitted from many commonly used definitions are characteristics including upstream speed, symmetric capabilities and the ability to support many applications and user devices simultaneously. These important omissions have led to the use of terms such as enhanced or ultra broadband (see [ACG, 2003]).

At the infrastructure level, broadband transmission is provided by a wide range of technologies, including Digital Subscriber Line (DSL), Fiber optic cable, Coaxial cable, Wireless and Satellite. [Fijnvandraat and Bouwman, 2006] study addresses broadband technologies and potential technological evolutionary paths for broadband. At the services level, broadband allows the convergence of voice, video, and data services into a single network.

The term broadband is contrasted with narrowband. Generally speaking, narrowband describes telecommunication systems that carry voice and data information in a narrowband of frequencies. More specifically, the term has been used to describe a specific frequency range set by the FCC for mobile or radio services. Typical technologies associated with narrowband are dial up connections running up to 56 kbit/sec and ISDN dial up connections which run either as 64 or 128 kbit/sec. According to [Ofcom, 2005], the term 'broadband' refers to higher bandwidths and 'always on' services offering data rates of 128 kbps and above. Dial-up or narrowband refers to Internet access that offers speed equal to or below 128 kbps.

1.2 Broadband potential

In the recent past there is an emergent recognition that "broadband networks" are important public infrastructures. The FCC Commissioner Michael J. Copps has observed: "providing meaningful access to advanced telecommunications for all our citizens may also spell the difference between stagnation and economic revitalization. One study estimates that universal broadband access could add half a trillion dollars to the U.S. economy every year. Even that may be conservative. Broadband is already becoming key for our nation's systems of education and commerce and jobs and, therefore, key to America's future. It's going to be front-and-center in America's twenty-first century transformation" (see [Ford and Koutsky, 2005] and [Firth and Mellor, 2005]). In 2004, ex-President Bush stated that "this country [U.S.] needs a national goal for the spread of broadband technology. We ought to have universal, affordable access for broadband technology by the year 2007, and then we ought to make sure as soon as possible thereafter, consumers have got plenty

of choices when it comes to [their] broadband carrier" (see [Crandall et al., 2007]). Similar positions have been adopted in Europe, where the European Commission has concluded that "widespread and affordable broadband access is essential to realize the potential of the information society" (see [EU, 2005]). According to UK ex-Prime Minister Tony Blair and Swedish ex-Premier Goeran Persson "broadband communication is a key element of Europe's future competitiveness" (see [TA, 2002]).

Broadband deployment has the potential to bring valuable new services, stimulate economic activity, improve productivity, and advance economic opportunity in the EU and around the world (see [Loannis and Anastasia, 2005]). The benefits of broadband in terms of productivity gains, growth, and employment are expected to be significant. Broadband infrastructures and new services will be a major source for job creation in industry and services, will give a thrust to accelerate technological innovation, and will be a physical backbone for the knowledge economy. Widespread availability of broadband infrastructure will also impact on growth by improving the performance of services that change the way companies and public administrations work (see [Loannis and Anastasia, 2005]). The diffusion of broadband and wireless developments are expected to encourage organizational changes and fuel associated productivity gains, and mobility is gaining importance, in particular with the diffusion of mobile broadband. Broadband generates increased efficiency, productivity and welfare gains, and potentially contributes to job creation and occupational change (see [OECD, 2008]). According to [BCC, 2003] report, broadband has the power to transform business, not just through faster downloads of emails and attachments, but also by enabling companies to be more productive and competitive by using e-enabled applications. A broadband connection opens up a wide range of opportunities for businesses, including enabling them to link directly to their customers and suppliers, to access key accounts from multiple locations, and to communicate effectively from a distance via video conferencing.

Broadband will bring economic as well as social benefits. It will contribute to e-inclusion, cohesion and cultural diversity. It offers the potential to improve and simplify the life of all Europeans and to change the way people interact, not just at work, but also with friends, family, community, and institutions (see [Anderson and Raban, 2005]). For many knowledge workers, residential broadband connections is a pre-requisite for working at home enabling productive use of non-traditional working hours, flexible work arrangements, or remote employment, or for establishment of home-based business (see [Gillett et al., 2006]). [BSG, 2004] found that "...full exploitation of broadband-enabled ICT, content, applications and services can help the UK to become a truly competitive knowledge-based economy and can be leveraged to help the UK's citizens become healthier, better educated and more engaged in their communities and society. ...Societies that adopt, adapt, and absorb the benefits of broadband enabled ICT, services and applications quickly and deeply will achieve significant benefits in terms of productivity, innovation, growth and quality of life as well as significant competitive advantage over societies that don't...". In 2008, [CBTF, 2008] observed that without broadband, communication is limited, innovation is stifled, productivity decreases, and quality of life is depressed. With broadband, the potential for economic development is an order of magnitude greater.

[Zilber et al., 2005] mention in their report: "broadband is much quicker, we

spend less time viewing and downloading needed material. Large files are sent quickly. Dial up would not permit us to send large files nor import graphics". [Firth and Mellor, 2005] present the benefits of broadband over narrowband: "broadband has the potential to offer the nation improved quality of education and health services, improved connectedness of government with society, and to provide jobs and prosperity. Broadband offers the home subscriber improved educational opportunities, entertainment diversity, and improved access to peers and to information networks". [Caroline and Karen, 2006] observed that accessing the Internet through broadband rather than narrowband technology enhances information search, use of e-government sites, and virtually any activity on the web. Broadband or high-speed Internet services provide users with faster and improved access to the Internet, making it easier to download graphics and information as well as open web pages without long waiting periods.

1.3 Motivation

There are already a significant number of studies on the economic impact of broadband infrastructures. [Lee et al., 2005] found out that the fast broadband deployment in Korea has contributed to the growth of economy. [SNG, 2003] referred to a case study prepared for the U.K.'s Department of Trade and Industry of a municipal fiber network built in 2000-2001 in South Dundas, Ontario, in which was found positive economic impacts from the local government investment. [Pociask, 2005] identified broadband investment as an important catalyst for operational efficiency in the U.S. In one study (see [Kevin, 2001]), it was shown that industries with higher capital stock in telecommunications and computing equipment experienced higher productivity gains. [Ferguson, 2002] observed that failure to improve broadband performance could reduce U.S. productivity growth by 1 percent per year or more, as well as weaken public safety, military preparedness, and energy security. Americans today enjoy an increasing array of broadband services, available from a growing number of service providers, using a variety of technologies. Relative to other countries, the United States has experienced superior productivity over the past several years (see [NTIA, 2008]). Another study (see [Fornefeld et al., 2008]) investigated the impact of adoption of value-added broadband services in organizations in Cornwall (UK) and Piedmont (IT). This study observed additional productivity increase in both regions due to broadband penetration.

Although the economic impact of broadband has been subject of many studies, the announced impacts were not yet backed up with factual evidences. In general, these studies tend to be more rhetoric, lacking specific and empirical grounding for their claims. [Thompson and Garbacz, 2008] corroborated this view stating that "there has been remarkably little detailed discussion about how high-speed Internet services have the potential to significantly improve an economy other than through massive investment". [Mackenzie, 2006] states that "the OECD's assessment of broadband importance to the overall economy doesn't explore that claim with any real substantial evidence". To conclude, [Lee et al., 2005] have stated that "while there are contrasting views on the relationship between broadband and socio-economic developments, there has been surprisingly little research to investigate the

link between them".

The explanation of the links between broadband and productivity is an essential input to the development of telecommunication infrastructures related public and private policies. This work contributes to explain the potential benefits obtainable from local government and organizational investments in broadband deployment or use. Hence, the practical value of this research falls into two groups: for the public decision makers responsible for telecom infrastructures aiming at justifying investments in more advanced form of infrastructure (e.g. in fibre to the home); and for managers from private organizations aiming at higher productivity gains.

1.4 Research questions

To address the relation between broadband and organizational productivity, this work investigates the following research questions:

1. What is the state of the art concerning the impact of broadband to organizational productivity?
2. Is there any thorough and generally accepted framework to investigate the relation from broadband to organizational productivity?
3. If not, which framework can be used?
4. How can the applicability of such framework be tested?
5. Which conclusions can be derived about the impact of broadband using this framework?

1.5 Contribution

This thesis lays down four main contributions for a valid ground to justify the large scale economic importance of broadband infratsructures:

1. A representative state of the art literature review about studies done on the economic impact of broadband.
2. The proposition to use a previously developed conceptual framework (labelled *Trans model* (see [Madureira et al., 2009])) to investigate the relation between broadband and organizational productivity.
3. A validation of the application of the Trans model to investigate the relation between broadband and organizational productivity using a literature review.
4. Development of a questionnaire using the Trans model. Based on this questionnaire, a survey was done to a relevant population to test the clarity of the questionnaire, to test the completeness of the framework, and to get a preliminary impression on the impact of broadband to organizational productivity.

1.6 Organization of the thesis document

The next chapter provides a summary of the findings from a state of the art literature review on the economic impact of broadband infrastructures. From this review, an analysis is done to find out if there is any thorough and generally accepted framework to investigate the relation from broadband to organizational productivity. This chapter discusses also the most relevant challenges related to this topic. In this chapter, the research questions 1 and 2 are addressed.

In chapter 3, a framework is proposed which can be used to investigate the relation from broadband to organizational productivity. This chapter introduces also a set of causal mechanisms identified in the proposed model, linking broadband to organizational productivity, which serve as the base for our framework. In this chapter, the research question 3 is addressed.

In chapter 4, a set of observations is distilled from a thorough literature review done on the relevance of broadband. By mapping this extensive, but scattered set of observations with the proposed model, the relevant outcomes of broadband are structured in a valid conceptual way. Furthermore, with this exercise it is proven the utility of the proposed framework for further studies on the productivity impact of broadband. In this chapter, the research question 4 is addressed.

In chapter 5, it is described the development and test of a questionnaire based on the proposed framework. In this chapter, it is tested the clarity of the questions, the completeness of the Trans model, and it also presents some preliminary results, which give a preliminary impression about the impact of broadband. In this chapter, the research question 5 is addressed.

Finally, in chapter 6, an overall summary of the results obtained in this thesis is presented and some recommendations are drawn for future work.

Chapter 2

State of the Art and Research Challenges

2.1 State of the art

There are already a significant number of studies on the economic impact of broadband infrastructures. This chapter presents an overview of a literature review survey done about studies on the economic impact of broadband.

The review does not aim to be a thorough survey, but to be a representative sample enabling us to take general conclusions on findings and methods. These studies were done over geographical regions ranging from local areas (e.g. South Dundas) to whole countries (e.g. U.S.). Moreover, in this work, the findings of these studies were classified according to the economic variable considered (positive, negative or unclear impact).

The majority of these studies were done on basic broadband and a few on enhanced broadband (e.g. systems in which fibres supporting optical communications are terminated with boxes located as close as possible to the end users). These studies were conducted mostly by universities (e.g. Brandon University, Simon Fraser University, Massachusetts Institute of Technology, etc.) or by consultancy companies (e.g. SNG, CEBR, ACIL Tasman, etc.).

In this work, the impacts were categorized using the following economic variables: *expansion of the telecommunication sector* (e.g. investment in infrastructures), *productivity*, *telecommunication sector competition* (e.g. number of providers, services and portfolios), *production*, *investment* (e.g. financial activity), *input demand* (e.g. goods and labor required to develop infrastructures), *wages* (e.g. by compensating employees for an output increase), *private consumption* (e.g. more expenditures in entertainment services), *employment* (e.g. by opening new positions), *population of firms* (e.g. by attracting new firms to a region), *taxation* (e.g. increased public revenues from taxing telecommunication revenues) and *trade* (e.g. by promoting new business relations with international partners).

The methodologies used by these studies can be classified into four types: *statistic*, *econometric*, *Input-Output (IO)* and *Applied General Equilibrium (AGE)*. The basic *statistic* studies apply simple statistical functions to surveys' data, simply aiming to confirm announced benefits of broadband relying on the individual opinion

of the interviewees. For instance, the study of [Zilber et al., 2005] concluded that "almost 19% of business respondents in the Peace River region and over 15% of respondents in the South Similkameen region indicated that they could not operate without broadband". The econometric studies try to analyze and test relationships between data on broadband (e.g. adoption or availability) with economic variables (e.g. productivity). The IO studies use a matrix representation of a nation's (or a region's) economy to predict the effect of changes in one industry on others and by consumers, government, and foreign suppliers on the economy (see [Dietzenbacher and Lahr, 2004]). AGE builds upon the IO theory and the Walrasian equilibrium theory to produce an aggregate representation of the economy with the markets in equilibrium, in the sense that for each commodity and factor, their prices are adjusted so that demands added across all the actors do not exceed total supplies (see [Tesfatsion, 2005]). AGE allows to derive indirect effects of policies within a Walrasian equilibrium framework.

Among the four types, the basic statistic studies are the ones offering better insights on the impacts of broadband. The reasons are twofold:

- The hypothetical effects are validated by the users, which are the economic agents directly affected by broadband. The other types of studies offer weak or simply do not offer validation of their results.

- Any economic quantitative finding is typically accompanied by a more detailed economic, social or psychological qualitative explanation, which is essential to underpin the effects of broadband.

On the other hand, these studies suffer from a limited scale of observation and are hampered by the subjective replies from the interviewees, limiting the results regarding, for example, extrapolation. Furthermore, none of these studies provides a framework for their analysis, hampering the completeness and orthogonality of their outcomes, and their usefulness for further studies. Despite these limitations, they provide the initial ground to reach large scale quantitative evidences of the economic impact of broadband.

The *econometric* studies aim to perform a macro analysis to evidence aggregated effects of broadband at the state or country levels. One of the main challenges they have to deal with is the availability of data. For example, [Gillett et al., 2006] pointed that their study was limited by the use of broadband availability (at the zip code level) as a proxy for broadband use. Moreover, the outcome of these studies is usually expressed with economic variables, such as productivity, that have many other conditionings. Finally, they do not properly underpin their econometric relation between broadband and productivity with intermediate economic, social or psychological variables. Thus, one is left to conclude that even supported by some statistical significance, these findings could be just mere random results, and therefore impossible to reproduce.

The *IO* and the *AGE* studies rely on the direct effects announced by the econometric studies to extrapolate their indirect consequences upon the economy. Therefore, based on the discussion above, they are vitiated from the start in their assumptions. Moreover, the empirical validation of IO and AGE models is itself matter of

dispute and controversy in the research community (see [Borges, 1986]). The apparent speculative character of these studies is reinforced by the fact that several of them attempt to evaluate the impacts of enhanced broadband, while the studies on the impact of basic broadband, scientifically speaking, are still small.

The difference between basic broadband and enhanced broadband networks is based upon the users' applications. Basic broadband supports multi-user devices, dual services (internet plus telephony), allows users to enjoy rich information exchange (e.g. using rich email and web browser), e-commerce activities, asymmetric (limited interactivity) speeds, and graphic capability. While narrowband is limited to single user devices, single service (internet or phone), allows users to exchange information (e.g. with basic email, basic web browser), asymmetric (no interactivity) and text capability. Enhanced broadband is capable of delivering symmetric speeds, supports multi-users devices, allows users to enjoy multi-services (internet, plus phone, plus video or TV), information exchange (e.g. with rich email and web browser). Enhanced broadband enables sophisticated interactivity, this in turn enables online applications including on-line class-rooms and health clinics where teacher and student and doctor and patient can interact in real time. It also creates the potential for entertainment services such as Video-on-Demand (VoD) and online gaming. Applications such as these have, to date, not been enabled by ADSL and cable technologies (see [ACG, 2003]).

The table 1 below presents an overview of the literature review done about studies on the economic impact of broadband.

Method	Reference	Region	Infrast-ructure	Economic Factors											
				Telecom Expansion	Productivity	Telecom competition	Production	Investment	Input demand	Wages	Private consumption	Employment	Population of firms	Taxation	Trade
Statistic	[SNG, 2003] (1)	South Dundas, Canada	B									▲			
	[Zilber et al., 2005]	Peace River and South Similkameen, Canada	B		▲				▼	▲	▼	▲			
	[James and Hopkinson, 2005]	Cornwall, UK	B		▲		▲		×			▲			
	[Annis et al., 2005]	Parrsboro and Churchill, Canada	B				▲		▼			▲			
Econometric	[Ford and Koutsky, 2005]	Lake County, Florida, US	E								▲				
	[Gillett et al., 2006]	US	B							×	▲	▲	▲		
	[Crandall et al., 2007]	US	B				▲					▲			
	[Shideler et al., 2007]	Kentucky, US	B									▲			
	[Thompson and Garbacz, 2008]	US	B		▲		×								
IO	[SNG, 2003] (2)	South Dundas, Canada	E	▲	▲		▲		▼			▲	▲	▲	
	[Standish et al., 2007]	Cape Town, South Africa	E	▲	▲		▲		▲	▲		▲		▲	
AGE	[ACG, 2003]	Queensland, Australia	E	▲	▲	▲	▲	▲		▲	▲	▲			
	[CEBR, 2003]	UK	B		▲		▲	▲			▲				×
	[ACIL Tasman, 2004]	Victoria, Australia	E		▲		▲					▲			
B: Basic Broadband E: Enhanced broadband				▲: positive ▼: negative ×:unclear											

Table 1: Resume of the studies done on the economic impact of broadband

The important conclusion that can be drawn from these studies, done on the economic impact of broadband is that these studies found in general broadband to be important boosting the economy. Table 1 above provides evidences of the findings on broadband impacts. In general, these studies have found in common positive impacts on many economic variables. They investigated the impact of broadband on different geographical areas and found similar impacts which qualify the value of broadband. The results of the majority of these studies are exciting; they found positive impact on many economic variables (e.g. productivity, employment, and production, etc.). Only one study found a negative impact on private consumption (the study of [Zilber et al., 2005]). Concerning the 'input demand' economic variable, the majority of these studies observed a negative impact due to the development of the telecommunication infrastructures. However, not all the studies investigated the impact of broadband to all the economic variables resumed in this table, but the majority did on the important ones (e.g. productivity, employment, and production) and found a considerable excitement about the potential effects of broadband.

2.2 Research challenges

There are many challenges in the process of finding empirical evidences of the economic value of broadband. Measuring the productivity impacts of broadband confronts the same type of challenges found in previous studies that led to the so called Information Technology (IT) productivity paradox, best articulated by the economist Robert Solow: "we see computers everywhere except in the productivity statistics" (see [Solow, 1987] and [Gillett et al., 2006]). As with computers, the effects of broadband can be better observed in the services industries (i.e. non-farm, non-manufacturing) where productivity improvements are typically less well captured by economic data. Early studies suggested that broadband should make individuals and businesses more productive through behaviours such as online procurement and telecommuting. However, data is generally not available, to observe these behaviours at the local level across the entire nation. [Annis et al., 2005] observed that factual proof of broadband benefits is needed but is often difficult to quantify, and despite limited resources and budgets there is an increasing pressure to demonstrate results. Broadly speaking, these challenges can be summarized into five categories: *1) causality; 2) separability; 3) externality; 4) endogeneity; and 5) availability*. In the following subsections, each one is described.

2.2.1 Causality

The causality mechanisms that lead broadband to economic productivity implications necessarily involve human and social behaviors, because it is at this level that broadband has its primary effect. Obviously, these behaviours are difficult to account, theoretically as well as empirically, particularly with the analytical tools traditionally used in economics. [Granovetter, 1985] pointed out that a fundamental difference between economics and sociology is that sociologists take it for granted that humans are socially embedded (see also [Bourdieu, 1986]). Contrary to sociology, economic theory rests on the absence of social embeddedness. The consistency principle is one of the most stark evidences of the existence of social embeddedness (see [Moss, 2007]). Effectively, it states that humans tend to agree with those whom they share interests and social background (see [Brown, 2003]). Broadband infrastructures provide the network substrate to social economic actors, and therefore, to understand their impact on economic productivity, one must also be able to connect the dots from partially rational individual actors to systemic large scale economic patterns.

2.2.2 Separability

This challenge refers to the separation of the effects of broadband from the ones caused by IT and narrowband. Broadband acts in conjunction with IT systems, and therefore, the separability of their effects is not an elementary task. Comparing to narrowband, broadband offers richer and faster communications. For the case of adoptativity, this might be translated in the transfer of knowledge via real time video streaming. [Crandall et al., 2007] approach does not attempt to divide telecommunications infrastructure capital from the rest of the capital stock. [ACIL

Tasman, 2004] indicates that the task of quantifying likely productivity gains due to broadband in different sectors of the economy largely depends upon more general observations from business adoption of ICT and internet in general.

2.2.3 Externality

Externality refers to indirect effects of broadband that happen across organizations, and therefore are difficult to quantify. These effects are also called spillovers effects. [Thompson and Garbacz, 2008] recognized that a better understanding of broadband's impact may lie in exploring the network externality effects associated with its use. [Crandall et al., 2007] have mentioned that the network externalities will have the most significant economic impact, but that we will not see these for some time yet as they may take time to disperse through an economy. [Pociask, 2005] observed that the creation of IT jobs can have large spillover effects into other industries. For example, one report estimated that every Microsoft job leads to the creation of 6.7 other jobs. [Gillett et al., 2006] suggested that while online banking and shopping may make local workers more productive, it is also likely to put competitive pressure on local banks and retail stores, leading to ambiguous effects on the number of local jobs.

2.2.4 Endogeneity

The endogeneity challenge refers to number of factors effecting productivity. Several other factors (e.g. economic freedom (see [North, 1990]), political stability (see [Friedman, 1962]) may affect productivity. Therefore, they should be endogenous in the analysis. [Ford and Koutsky, 2005] addressed this issue by observing that two communities were nearly identical in terms of economic growth over some specified period of time. After this period, one of the communities made available one broadband infrastructure. During this period, they observed a divergence in economic growth rates. The difference in the growth was then attributed to the broadband infrastructure.

2.2.5 Availability

Broadband is a relatively new phenomenon. Hence, there is a general lack of sufficient data to analyze the induced changes due to the newness of broadband. [Ford and Koutsky, 2005] claim for the general lack of sufficient economic and demographic data to analyze changes in a community's economic wealth. This view is corroborated by the acknowledgement of [Thompson and Garbacz, 2008] on the relative newness of the phenomenon and the resulting paucity of data.

2.3 Discussion and conclusion

From the summary of the previous studies, there is considerable excitement about the potential effects of broadband not only on internet use, e-commerce, wealth, entertainment, etc., but also in other economic factors. Broadband investment appears to provide substantial benefits to both consumers and the overall economy. Broadband investment and services appear to stimulate economic output, increase productivity, telecom competition, cost reduction and increase tax revenue as well as create jobs.

Despite this general perception, these effects were not yet backed up with factual evidence. In general these studies tend to be more rhetoric, lacking specific and empirical grounding for their claims, simply relying on analysis and correlation of data, and not explaining thoroughly why these correlations should exist.

Concerning the general methodologies used, the statistical types of studies are the ones offering better insights on the impacts of broadband. However, they lack a thorough and generally accepted conceptual framework to categorize the impacts.

In the next chapter, this thesis describes a previously developed conceptual framework that allows to structure the relevant outcomes of broadband to organizational economic productivity in a valid conceptual way. Advances in this conceptual framework, both theoretically and empirically, might lead it to be applicable in the future to explore econometric and even IO and AGE types of studies.

Chapter 3

Theoretical Background- the Trans Model

3.1 Introduction

In previous work, the authors [Madureira et al., 2009] have developed a causal model that underpins the causal relation from Digital Information Networks (DINs) to organizational productivity.

Digital Information Networks refer to information networks supported by telecommunication infrastructures and terminated by microprocessors. DINs enable the networking of individuals in the digital economy: "an economy that depends on digital products and services in any of the production, distribution and consumption stages" (see [CBS, 2008]). Consumers use DINs to become more productive within the economic environment that surrounds them.

Productivity refers to the traditional economic definition (see [Jorgenson and Griliches, 1967]): a summarized measure of performance (P), based on the ratio of the total value of output (O) divided by the total value of input (I):

$$P = \frac{O}{I}$$

Being broadband a particular case of DINs, this thesis work hypothesizes that the Trans model can be used as the framework to investigate the relation between broadband and organizational productivity. At the moment, the work of [Madureira et al., 2009] is still under revision. Thus, it is still preliminary and for which the author of this MSc work does not hold responsibility. In this chapter, we transcript the work in [Madureira et al., 2009] to provide a clear understanding of the framework used in this thesis work.

The authors have labeled their model *Trans* because it identifies in a very high abstract level the mechanisms that motivate the economic agents to *trans*mit information (see figure 1).

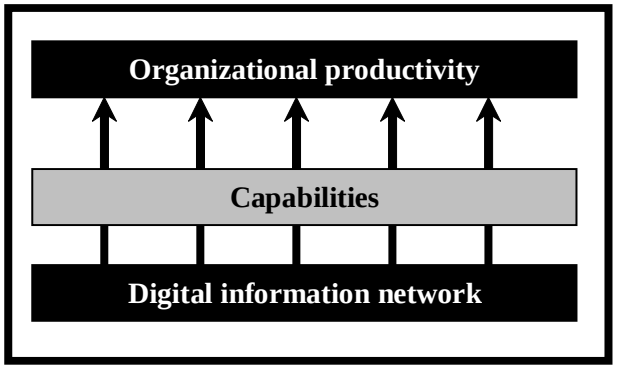


Figure 1. Trans model

In the next section, a definition of *capability* is given which is [Madureira et al., 2009] conceptualization of a direct causal mechanism linking DINs to organizational productivity.

3.2 Capabilities

Network externality can be defined as a change in productivity that an agent derives when the number of other agents using DINs changes. This allows, in principle, to separate the value of productivity in two distinct parts. One component, the *autarky* value (following the nomenclature of [Liebowitz and Margolis, 1994], is the productivity value if there are no other agents using DINs. The other component, the *connection* value, is the additional productivity value achieved when multiple other agents are using DINs. The latter value is the essence of DINs' externality effects. From these observations, [Madureira et al., 2009] define *digital economic agent* in the following way:

Definition: *Digital economic agent is any agent from an economic structure which may achieve an additional productivity value when multiple other agents are using DINs.*

Examples of agents are workers, consumers and producers from any organization using DINs. From here on after, the authors use *economic agent* or simply *agent* to refer to *digital economic agent*. An agent explores personal and intrinsic capabilities to become more productive within his economic structure. For example, consumer A meets supplier B to acquire a production input at a lower price. The capability of A and B to meet each other will make both more productive. From a thorough literature review on the relation between information, digital infrastructures and productivity, [Madureira et al., 2009] have identified a set of capabilities of a productive economic agent, which are directly dependent on DINs. [Madureira et al., 2009] hypothesize these capabilities to be generally applicable to agents across all economic sectors. Before introducing these capabilities in the following subsections, [Madureira et al., 2009] define *capability* as:

Definition: *Capability is a quality of the economic agent used for productive purposes and directly affected by DINs.*

3.3 Sensitivity

[Granovetter, 2005] found that when the number of relationships between agents increased further than what they could retain, communication between them became difficult and at that time, the group broke into cliques [Kirman and Vignes, 1991]. Moreover, he observed that prices in very large organizations were more volatile than in small ones, and proliferation of cliques resulted in additional overall volatility. Theoretically, in conditions of perfect information sensing one would expect prices to converge. From these observations, [Madureira et al., 2009] define *sensitivity* as:

Definition: *Sensitivity is the capability of an economic agent to sense information from other agents.*

High capacity communication infrastructures often directly influence sensitivity. Broadband is expected to expand research and knowledge sharing capabilities (see [ACG, 2003]). On the other hand, it may cultivate passivity, restrict imagination, and inhibit creativity (see [Firth and Mellor, 2005]).

3.4 Trustability

A risk-averse decision maker will pay premiums to insure against any arbitrary risk (see [Pratt, 1964]). While firms are traditionally assumed to be risk neutral, economists have increasingly recognized situations in which they may be risk averse instead (e.g. capital markets) (see [Stiglitz, 2000]). Efficiency gains can be realized through information mechanisms that prevent poor transactions (for a labor market example see [Spence, 1973]). Trust is one of them, defined by [Granovetter, 2005] as the confidence that others will do the right thing despite a clear balance of incentives to the contrary. [Madureira et al., 2009] adopt [Granovetter, 2005] definition to define *trustability* as:

Definition: *Trustability is the capability of an economic agent to have confidence that other agents will do the right thing despite a clear balance of incentives to the contrary.*

But trust does not always unambiguously improve productivity. [Uzzi, 1996] argues that trust offers advantages in stable situations, but in periods of changes, it locks firms into relationships and may inhibit adaptation. [Wellman et al., 1996] and [Constant et al., 1996] studied the effect of DINs in trust ties. Both concluded that computer-supported weak ties were more helpful that strong ones for gaining access to information. [Katz and Rice, 2002] provide many examples of online relationships enhancing conventional ones.

3.5 Normativity

Norms, being shared ideas about the proper way to behave, are one of the oldest arguments in social psychology (see [Festinger et al., 1948]). They foster network effects by promoting economies of scale, and at the same time reduce information processing requirements by constraining potential interpretations (see [Balakrishnan et al., 1995]). On the long run, they can have negative effects, masking changes in the environment. [Madureira et al., 2009] define normativity as:

Definition: *Normativity is the capability of an economic agent to share with other agents ideas about the proper way to behave.*

One important example of norms is loyalty systems (see [Granovetter, 2005]). DINs can displace individuals from conventional social contacts, and therefore affect their productivity (see [Katz and Rice, 2002]). Another negative example comes from intellectually free property rights (see [Firth and Mellor, 2005]): e.g. unsupported open software can cause operational delays within organizational structures, and consequently inefficiencies in production. More positively, public measures have been established to promote cohesion and cultural diversity using digital communications (see [Anderson and Raban, 2005]). [Hojman, 2004] studied long run equilibrium patterns in coordination games in the presence of conventions.

3.6 Hierarchity

Another mechanism potentially useful to increase efficiency is a *hierarchical structure*. [Williamson, 1975] shows the importance of hierarchies in companies, titling his book on transaction cost economics "Markets and Hierarchies" equating the *company* with *hierarchy*. [Madureira et al., 2009] define *hierarchity* as:

Definition: *Hierarchity is the capability of an economic agent to be ranked differently than other agents in the organization.*

Within organizations, one has to balance the importance of global information favoring hierarchical centralization, with local information gathering enabling fast local organization adaptation, favoring decentralization. Productivity increases to the extent that distributing control optimally balances these factors in the light of complementarity and indispensability (see [Bulkley and Alstyne, 2004]). Information management theory then offers results on how to use DINs to explore [Bulkley and Alstyne, 2004] core insight (see [van Alstyne and Brynjolfsson, 1995]). One example is *indispensable agents should exercise greater control*. Also the communication between organizational structures becomes more efficient, with services being delivered by specialized providers (see [Fornefeld et al., 2008]).

3.7 Coordinativity

Coordination is *"the act of managing interdependencies between activities performed to achieve a goal"* (see [Malone and Crowston, 1990]). It arises, effecting productivity, when the agent has to choose between actions, the order of the actions matters and/or the time at which the actions are carried out matters (see [Decker and Lesser, 1994]). Therefore:

Definition: *Coordinativity is the capability of an economic agent to manage interdependencies between activities with other agents to achieve a common goal.*

Coordinativity prevents conflicts, waste of efforts, and squandering resources, and assures focus, while trying to accomplish a common goal. The work of [Kandori et al., 1993] and [Young, 1993] have triggered much interest in coordination games. Important research results concern the impact of different network structures in coordination (see [Kosfeld, 2003]). In a survey performed by [James and Hopkinson, 2005], 45% of the respondents identified DINs as a driver to reorganize work practices. More specifically, online banking can be seen as a good example of an application of digital coordination (see [ACG, 2002]).

3.8 Cooperativity

Cooperation can be defined as *acting together with a common purpose* (see [Hua, 2004]). Sharing information helps agents aligning their individual incentives with outcomes. Assuming proper behavior, if absolute incentives are more advantageous over relative incentives, the agents cooperate. Both inter- and intra-organizational cooperation have been object of study since the work of [Marshall, 1890]. Good examples are joint ventures. Therefore:

Definition: *Cooperativity is the capability of an economic agent to align his personal goals with individual goals from other agents for a common purpose.*

In practice, it is often hard to distinguish cooperativity from coordinativity. Conceptually, the key differences are two:

1. In coordinativity the agents share exactly the same goals, while in cooperativity the agents share only partially aligned goals;

2. And in coordinativity the relation between the agents is critically dependent on time, while in cooperativity the agents relate to each other typically *offline*.

Although the experimental literature on cooperation is vast (see [Kosfeld, 2003]), only a few papers consider the role of networks in this process (see e.g. [Vega-Redondo, 2002]). Supply and demand matching with online trading is an important practical example of the importance of DINs for cooperativity (see [Annis et al., 2005] and [Lee et al., 2005]).

3.9 Selectivity

Selection is the process of scanning for the unknown or generating courses of action that improve on known alternatives (see [Bulkley and Alstyne, 2004]). For maximal productivity, the agent has to decide for a stopping point in an uncertain environment (see [Diamond, 1989]), while keeping computational requirements within limits. Therefore:

Definition: *Selectivity is the capability of an economic agent to scan information from other agents, generating courses of action that improve on known alternatives.*

The role of information networks has been extensively acknowledged in this process (see [Watts et al., 2002]). A practical proposal accounting the value of networks in the process of selection has been made in [Saaty, 2001]. This framework has been used for interdependent information system project selection (see [Karsak et al., 2003]). Online job hunting and Google.com are good example of selectivity using DINs.

3.10 Negotiability

Negotiability occurs when exchange happens between unfamiliar partners or when evaluating new courses of action. Negotiation grows in importance with the perception that potential downside effects of a wrong decision can be large and costly to reverse. Negotiability mechanisms include signaling (e.g. give guarantees to buy) and screening (e.g. give certificates to sell) (see [Akerlof, 1970] and [Spence, 1973]). Economic literature further distinguishes between one shot and repeated contracts (see [Tirole, 1988]). [Madureira et al., 2009] define *negotiability* as follows:

Definition: *Negotiability is the capability of an economic agent to bargain with other agents for inferior exchange costs.*

[Kranton and Minehart, 2001] developed a model in which the prices are determined by a bargaining process rather than an English auction. However, the precise influence of the network structure in negotiation processes has not been intensively studied yet (see [Fischbacher et al., 2003] for some experimental work). Online stock trading activities are a good example of the importance of DINs for negotiability (see [Zilber et al., 2005]).

3.11 Adoptativity

[Nelson and Winter, 1985] state that firms improve their productivity by adopting technological and organizational solutions from the most innovative firms (see also [Dosi, 1988] and [Mazzuccato, 2000]). Examples are informal associations (see [Saxenian, 1994]) and product advertisement (see [Griliches, 1958]). Important dimensions to be accounted are the level of codification (see [Winter, 1987]) and the

extent to which the knowledge fits in a set of interdependent elements (see [Winter, 1987] and [Teece, 1986]). This leads to:

Definition: *Adoptativity is the capability of an economic agent to adopt knowledge from other agents.*

There is a vast literature studying *adoptativity* using network analysis. It started with [Rogers, 1958], and [Ryan and Gross, 1943] studying adoption of pesticides by rural sociologists, and [Strang and Tuma, 1993], [Burt, 1987] and [Coleman et al., 1966] studying the adoption of medicines. Many examples could be cited of the value of digital networks to exchange knowledge. A good example is e-learning between students (see [Bauer et al., 2002]).

3.12 Creativity

Agents can increase their productivity by creating new knowledge by collaborating with other agents to address operational inefficiencies. Their motivation to collaborate comes from indivisibilities of their specialized knowledge (see [Teece, 1980]) and environmental changes. Organizations that best address crucial information gaps through their information network structures may be more able to create novel knowledge. Thus:

Definition: *Creativity is the capability of an economic agent to create new knowledge, unknown to him before and to his collaborative agents.*

The relevance of DINs for collaborative research is well recognized (see [OECD, 2008]), and evidences have been found that organizations that use them more intensively, innovate more (see [Koellinger, 2006]). A trade-off exists between rate of information gathering and rate of environmental change (see [Bulkley and Alstyne, 2004]).

The capabilities of the economic agent are somehow effected by digital information networks with implications for organizational productivity. [Madureira et al., 2009] provided a more details in the causal structure of the Trans model by grouping capabilities into three layers (sensit, jungit and intelligit (see figure 2)). Each layer has a unique character, making it possible to establish a dependency rule between them: the layers above are dependent on the layers below. Starting top-down, the first layer is intelligit, followed by jungit, and finally sensit. From an economic perspective, the function of the agent is to choose and perform between alternative rational capabilities to navigate through the production space problem. These capabilities (adoptativity, creativity, selectivity, negotiability, coordinativity, and cooperativity), identified in the intelligit layer (meaning to think), entitle the economic agent to be in a higher state of productivity. The jungit layer (meaning to join) encompasses the capabilities which enable an agent to establish relationships (trustability, normativity and hierarchity) with other agents. Jungit capabilities'

effects in productivity might be positive or negative. The sensit layer (meaning to sense) encompasses one capability (sensitivity) which enables an agent to sense information. An agent might be sensible to information quality and quantity.

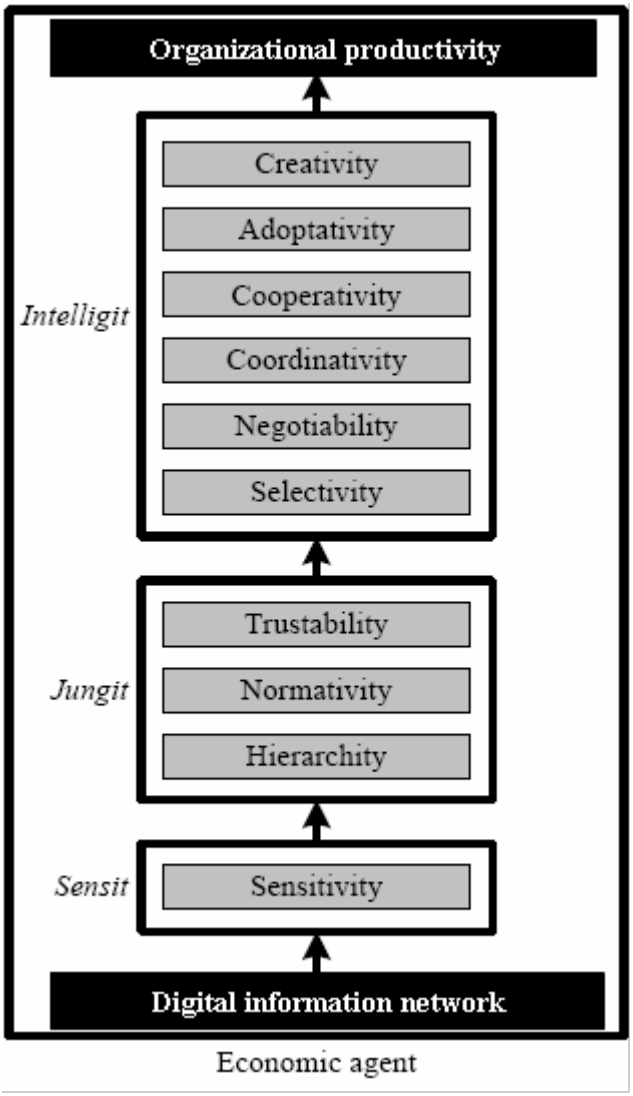


Figure 2: Trans causal structure

3.13 Discussion and conclusion

In this chapter, the theoretical background for this thesis work was laid down. It consists of a causal model, labelled Trans, that underpins the relation between digital information networks and organizational economic productivity.

The model has been developed by [Madureira et al., 2009], and it is still in a preliminary stage. At a higher level of detail, Trans identifies capabilities (sensitivity, trustability, hierarchity, normativity, coordinativity, cooperativity, adoptativity, creativity, selectivity, and negotiability) of the economic agent somehow effected by digital information networks. At a lower level of detail, capabilities are structured in layers (sensit, jungit and intelligit).

Being broadband a particular case of digital information networks, this thesis work hypothesizes that the Trans model can be used as the framework to investigate the relation between broadband and organizational productivity.

In the following chapter, a set of observations is distilled from a thorough literature review done on the relevance of broadband. By mapping this extensive, but scattered set of observations with the Trans model, the relevant outcomes of broadband are structured in a valid conceptual way. Furthermore, with this exercise it is proven the utility of the Trans model for further studies on the productivity impact of broadband.

Chapter 4

From Broadband to Productivity- with the Trans Model

In this chapter, we distill and transcript a set of observations from a thorough literature review done on the relevance of broadband. By mapping this extensive, but scattered set of observations with the Trans model, the relevant outcomes of broadband are structured in a valid conceptual way. Furthermore, this exercise it is validates the utility of the Trans model for further studies on the productivity impact of broadband.

4.1 Sensitivity

High capacity communication infrastructures have a direct relation with sensitivity. Broadband is important to captivate users as it supports a richer, more interactive content, increases reliability, and thus, offers a more satisfying experience (see [DTI, 2005]).

[Dwivedi et al., 2008] have studied the differences between narrowband and broadband in respect to service quality perception. They concluded that the service quality provided by broadband significantly influences the consumers' behaviour. Survey results from [James and Hopkinson, 2005] state that the main benefits of broadband are better access to information (93% of 433 respondents shared this opinion) and ability to provide a more professional image to customers (87% of the respondents).

On the other hand, broadband access to wide and rich information may cultivate passivity, restrict imagination, and inhibit creativity (see [Firth and Mellor, 2005]).

4.2 Trustability

[Fornefeld et al., 2008] address organizational changes due to broadband in respect to business-process outsourcing. They remark that "this kind of relationship between companies is strongly conditioned by the presence of a broadband link". Such relationships would be impossible without trust between the parties on the quality and reliability provided by their broadband infrastructures. [Venkatraman, 2007]

provides examples of this trans-sector networks: Apple with Disney and Google, Google with publishers and portals, etc.

In a survey by [James and Hopkinson, 2005], 80% of the respondents found broadband useful to achieve a better relationship with customers and 66% to a achieve a better customer base. [AT and T, 2003] state that "the increasing availability of affordable broadband connections ... is fostering more confidence in remote work". In the same paper, they quote a senior manager referring to broadband as "one of those few business strategies that not only improves the bottom-line, but one that places more trust in employees".

From the governmental perspective, [BSG, 2004] addresses the relevance of broadband stating that the perception of services it enables to the users creates "additional public value by increasing trust and confidence in the government".

4.3 Normativity

Norms, being shared ideas about the proper way to behave, are one of the oldest arguments in social psychology (see [Festinger et al., 1948]).

[Anderson and Raban, 2005] state that "broadband enabled communications, in combination with convergence, will bring social as well as economic benefits. It will contribute to e-inclusion, cohesion and cultural diversity". A study by [OECD, 2008] reflects upon the effects of broadband in changing the culture of organizations. They mention that companies culture is "increasingly output oriented rather than location- or time-oriented. While increased flexibility is likely to have a positive impact on workers' productivity, companies can also start to save costs on office space".

A negative example is coming from the peer to peer movement and other software sharing applications. Some say these are the killer applications for broadband, but they raise intellectual property issues difficult to be dealt with (see [Firth and Mellor, 2005]). Another example comes from the Education sector. Many universities are providing their immense source of educational material online. Consequently, there is a risk of limiting the pluralism of ideas, analysis, and judgments.

4.4 Hierarchity

A mechanism potentially useful to increase the organizational efficiency is a hierarchical structure. Information management theory offers results on how to balance the importance of global information favoring centralization, with information gathering and adaptation favoring decentralization (see [Bulkley and Alstyne, 2004]).

[Fornefeld et al., 2008] point to the example of networks of companies and their specialized providers, stressing that these "distributed structures would not be possible without broadband infrastructures able to bring all participants of the business network close to one other". [SusTel, 2003] state that broadband allows teleworkers to keep contact with their hierarchical superiors, both with voice calls and video conferencing. Consequently, even without a close physical presence, the hierarchy of the company can be effectively respected and even optimized.

Other examples are coming from governmental initiatives. [Venkatraman, 2007] states that broadband is "challenging the structure and process of democracy with greater discussion online". [Awan, 2005] mentions that "the increase in capacity of storage and high broadband makes possible videoconferencing between the politicians and citizens to exchange opinions, ideas and discussion".

4.5 Coordinativity

Broadband has been generally recognized to facilitate coordination between people. [James and Hopkinson, 2005] provide results from a survey in which 45% of the respondents are reorganizing work practices as a result of broadband. Evidences can be found across many economic sectors.

In the finantial sector, [Lee et al., 2005] mention that the number of internet banking users has shown sustained growth throughout the period of broadband diffusion. They state that "this seems partly due to the fact that transactions have been made easier and faster to broadband and are therefore much more attractive to users". In the healthcare sector, [Lieberman, 2002] refers to "high-quality interactive video consultation that will change the way healthcare is delivered. Everyone will benefit from decreased lengths of hospital stays, improved specialist productivity, reduced travel, and more efficient management of care, personnel and expenditures". [TA, 2002] provides an example for the security sector: "airport security officials will need fast connections to match passenger data against current biometric or national security databases". In the transport sector, [Fornefeld et al., 2008] refer to a shipping company that reduced the delivery time from 14/15 to 1/3 days due to broadband.

4.6 Cooperativity

A very general form of cooperation happens between companies and consumers for supply and demand matching. [Annis et al., 2005] provide survey results that show a large number of organizations using Internet to purchase (69%) or sell (62%) goods and services. They state that these statistics are significantly higher for broadband users than for dial-up users. [OECD, 2008] points to the increased consumer choice by increased customization allowed by broadband, contributing to the sometimes referred to as long tail economy. Particularly, [Fornefeld et al., 2008] refer to online entertainment stating that "broadband internet allows essential innovations in delivering entertainment services to the user", not only due to "the higher available bandwidth, but also in the flat-rate pricing model". [OECD, 2008] states that "broadband can also enable small and medium-sized firms to cooperate and compete with larger firms". [TA, 2002] mentions a very practical example of robotic surgery and remote diagnosis allowing doctors to answer volunteerism calls around the world.

4.7 Selectivity

In general, an economic selection agent main task is to select relevant information (e.g. broker) from the information providers on behalf of end consumers.

Many examples could be provided of agents offering general services (e.g. Google and Yahoo) or specialized services (e.g. LinkedIn for job hunting and Hotels.nl for hotels selection). Broadband is an obvious requirement for their operation. On one hand, they have to load huge quantities of information. On the other hand, it is a requirement, both from the information providers and from the end consumers, that the information is rich and appealing. For this kind of companies (the so called Web 2.0 companies) advertisements, premiums and payed accessories are the sources of their major revenues (e.g. Google (see [Tarcsi, 2007])). As Web 2.0 companies are booming, all signs are pointing to the fact that residential users' bandwidth needs will soon equal the business use (see [Gillath, 2007]). Furthermore, high quality selectivity of information is essential for end consumers. [Uhrbach and van Tol, 2004] state that the "most telling indicator of whether a firm will purchase goods or services online is the presence of high speed Internet", because it allows them "to compare many suppliers and products very quickly".

4.8 Negotiability

Negotiability occurs when exchange happens between familiar and unfamiliar partners or when evaluating existing and new courses of action. Negotiation grows in importance with the perception that potential downside effects of a wrong decision can be large and costly to reverse. A good example of negotiability are stock trading activities, in which a few seconds of delay is unacceptable and the ability to prepare bids faster is important.

[Lee et al., 2003] mention that "online stock trading saw sustained growth throughout the period of broadband diffusion". [Davidson and Santorelli, 2008] cite an expert stating "you can't trade effectively with a dial-up connection, especially since most of these sites stream real-time market data". Another example is online gambling in sites like partypoker.com. [Ranger, 2005] refers to an expert stating "we know from earlier survey work that U.K. gamblers like the speed and convenience of betting online, and as the broadband boom continues, we expect more people to try online gambling". [Venkatraman, 2007], providing an example of a more traditional form of trade, mentions that broadband is helping farmers to get better prices for their production inputs.

4.9 Adoptativity

[Bauer et al., 2002] state that narrowband technologies are adequate for asynchronous adoption of knowledge, while broadband is required for synchronous (real time) learning configurations.

Data is available suggesting that there is a significant percentage of businesses engaging in e-learning (approximately 21% according to [ACG, 2002]). Broadband

enables knowledge adoption environments employing complex simulations, rich visualizations, immersive game playing scenarios, intelligent tutors and avatars, networks of learners, reusable building blocks of content, etc. Such environments meet "all learners' needs, and provide knowledge and training when and where it is needed, all the while boosting the productivity of learning and lowering costs" (see [TA, 2002]).

[Firth and Mellor, 2005] exemplify using improving skills of medical practitioners. [TA, 2002], referring to a US political commission, the Congress' Web-Based Education Commission, states that "broadband connectivity is a critical element of using information technology to transform and improve education", and they conclude by saying that "the experts clearly expect future innovations in learning technologies to ride and rely on high-speed networks".

4.10 Creativity

[Fornefeld et al., 2008] results show the creation of 440 000 jobs in business service sector in 2006 and 549 000 jobs in other economic sectors due to broadband-related innovation in knowledge-intensive activities. They add "service innovation and process innovation in knowledge-intensive activities strongly rely on broadband technologies".

[OECD, 2008] study mentions that broadband enables both innovation through development of new applications and the diffusion and further development of existing innovations, and these two channels mutually reinforce each other. [Koellinger, 2006] reinforces this view by mentioning that there is evidence that firms that use ICTs more intensively innovate more, creating larger spillovers and productivity gains. [TA, 2002] exemplifies with the particular case of biotechnology research.

4.11 Discussion and conclusion

In this chapter, the application of the Trans model to investigate the impact of broadband was tested using a literature review. Although the applicability was validated, the use of the Trans model within an econometric framework is still far. The gap lies in finding representative observational variables for the capabilities described. In practice, an economic agent performing a particular task often uses the capabilities intertwining them together. For example, when negotiating the price of an input, one would expect an agent to select information about prices from other input providers before bidding. Therefore, observational variables have to be found that can be exactly and exclusively associated to each capability.

Secondly, the Trans model addresses the causal relation from digital information networks to micro economic productivity. Thus, it is general enough to cover broadband. But, it does not include specificities uniquely associated to broadband. Therefore, further conceptual work is required to develop the framework to include these specificities, which in the most general sense are allowing digital information related tasks to be done *better* and *faster*.

In the following chapter, it is described the development and testing of a questionnaire based on the Trans model. The purpose of the questionnaire is to investigate

the impact upon organizational productivity, both for broadband and the general case of digital information networks.

Chapter 5

Questionnaire Development and Test

In this chapter, it is described the development of a questionnaire to evaluate the impact of broadband and digital information networks to organizational productivity. The questionnaire was designed based upon the Trans model. The validity of the Trans model to investigate the impact of broadband was shown in the previous chapter. Based on this questionnaire, a survey was done to a relevant population to test the clarity of the questionnaire, and to get preliminary impression on the impact of broadband to organizational productivity. Moreover, it was also tested the general case, the impact of digital information networks to organizational productivity. Two methods were used to deploy the survey: hard-copy delivery and online webpage. Finally, the completeness of the Trans model was also tested, by inquiring the interviews for other conceptual causal mechanisms not identified in the model.

5.1 Survey design

This section presents the design of the survey. This part was done in three steps:

1. Defining the goals and writing the cover letter.
2. Selecting the delivery methods.
3. Developing the questions for the questionnaire.

5.1.1 Goals and cover letter

The first step in any survey process is deciding what are the goals and the necessary information to be collected (see [Creative research systems, 2007] and [Ellen, 2002]).

The goals for this survey are defined as follows:

1. To test the clarity of the questions of the questionnaire.
2. To test the impact of broadband and digital information networks to organizational productivity.

3. To test the completeness of the Trans model.

Previous studies stated that a good cover letter should include the purpose and the use of the survey, assure to the respondents that the survey is anonymous and that their responses will be treated confidentially (see [Ellen, 2002], [Martin, 2006] and [Creative research systems, 2007]).

For this work, a cover letter was designed in a simple language in order to be easily understood by the majority of the participants (see appendix A). The cover letter starts with an introduction part which motivates participants to be part of the survey. Participants are explained about the purpose of the survey, and are assured about the confidentiality of their responses. An appeal is made to their cooperation to contribute to this research by completing the survey. Finally, it is provided names and email addresses of the research team members in order to permit respondents to ask any questions or concerns about completing the questionnaire or about their participation in the survey.

5.1.2 Delivery methods

Online surveys are valuable and informative type of surveys used to collect information in a very economical and fast way, because they can be emailed to the respondents. This makes this type of survey a better choice than other survey methods. On the other hand, online surveys should be limited to simple questions, whereas hard-copy delivery can include more complex questions.

Another step potentially useful in surveying online is the selection of a proper tool to be used. For the online webpage, an existing tool was used instead of designing a new one, allowing the saving of time, to reduce the complexity of the survey delivery process and to help focusing on the goals, the quality of questions, and other more relevant issues. [Tim, 2008] suggests that *"the survey tool should be professional to develop, administer, and analyze the survey"*. To qualify the tool to be used, the following requirements were considered for the selection of the survey tool:

1. The survey tool should permit the participants' identification in order to be able to view individual answers.

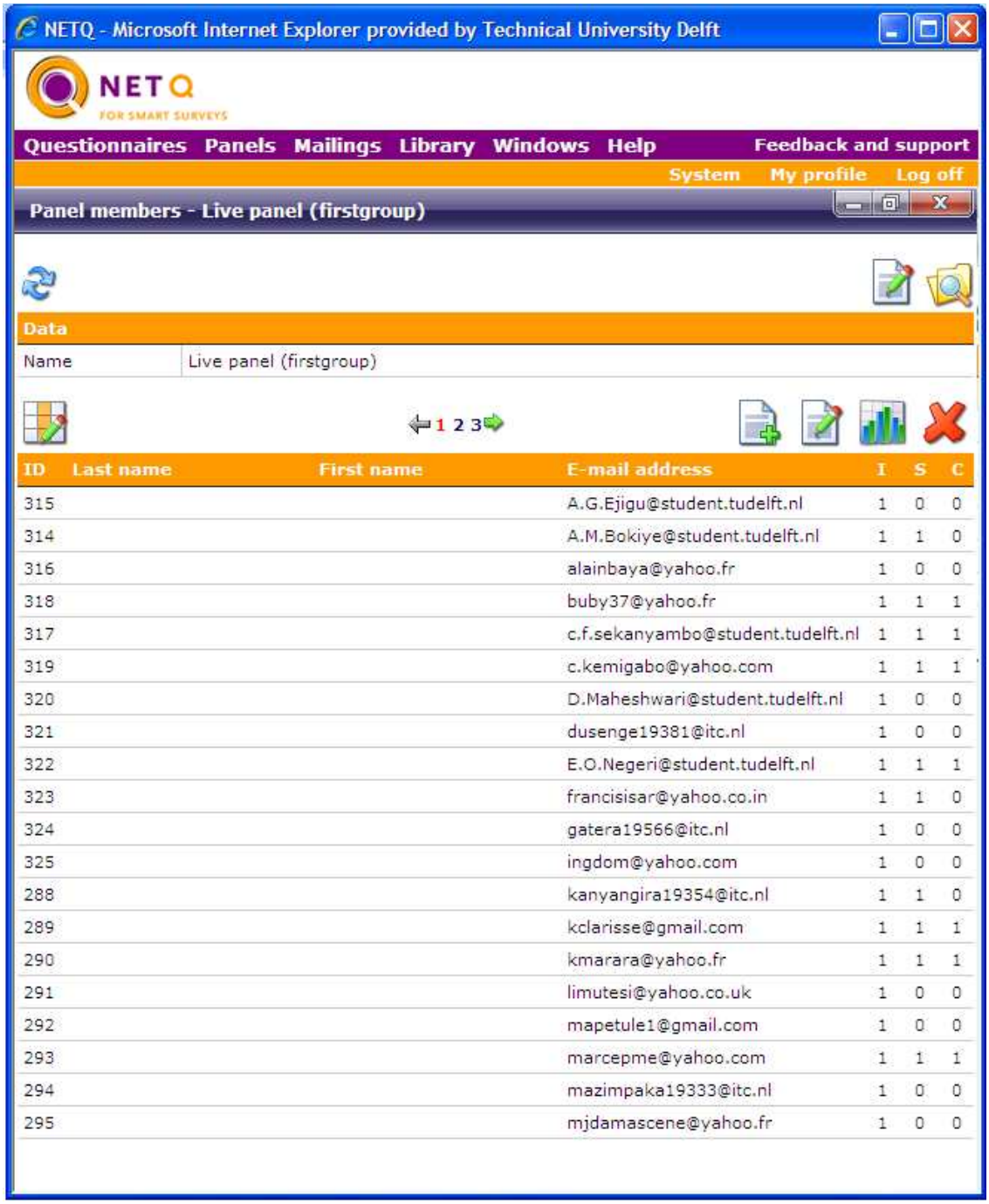
2. The survey tool should permit monitoring the survey progress.

3. The survey tool should allow respondents to complete questions only one time in order to avoid duplication of the answers.

The NetQuestionnaires (netq) online survey tool (see [NetQuestionnaires Nederland BV, 2005]) fulfilled these requirements. It was also chosen because TU Delft owns a license of it.

A progress indicator in the form of percentage display was added to the online survey to allow participants to know where they are while filling in the survey (see figure 5 and 6). This is an essential function to prevent people giving up before they finish the survey. Moreover, the netq survey tool allows monitoring the progress of survey by adding 3 columns for each participant with the titles (I, S, and C). These columns are numbers which indicate how many times this participant has

been invited (I) to participate in a survey, how many times he has started (S), and how many times he has completed (C) a survey (see figure 3 below).



ID	Last name	First name	E-mail address	I	S	C
315			A.G.Ejigu@student.tudelft.nl	1	0	0
314			A.M.Bokiye@student.tudelft.nl	1	1	0
316			alainbaya@yahoo.fr	1	0	0
318			buby37@yahoo.fr	1	1	1
317			c.f.sekanyambo@student.tudelft.nl	1	1	1
319			c.kemigabo@yahoo.com	1	1	1
320			D.Maheshwari@student.tudelft.nl	1	0	0
321			dusenge19381@itc.nl	1	0	0
322			E.O.Negeri@student.tudelft.nl	1	1	1
323			francisisar@yahoo.co.in	1	1	0
324			gatera19566@itc.nl	1	0	0
325			ingdom@yahoo.com	1	0	0
288			kanyangira19354@itc.nl	1	1	0
289			kclarisse@gmail.com	1	1	1
290			kmarara@yahoo.fr	1	1	1
291			limutesi@yahoo.co.uk	1	0	0
292			mapetule1@gmail.com	1	0	0
293			marcepme@yahoo.com	1	1	1
294			mazimpaka19333@itc.nl	1	0	0
295			mjdamascene@yahoo.fr	1	0	0

Figure 3: Monitoring the survey progress

The hard-copy delivery method was also used. On one hand, it is more accurate than the online method, because the personal presence of the interviewer motivates the interviewees to spend more time answering the questionnaire. On the other hand, it is not so efficient as it can be conducted only with a limited number of people. The questionnaires were distributed to identifiable and trusted people that could carefully answer the questions and then reply using mail box or personally. The hard-copy delivery method was primarily used to test the clarity of the questions and receive feedback about where and how to improve the questions' clarity.

5.1.3 Questions

Developing the questions for the survey is very critical and not an easy task. There are many scientific papers and reports (see [Dana, 2008], [Creative research systems, 2007], [Alix, 2008], [San Antonio College Institutional Research and Effectiveness, 2007], [Martin, 2006], and [NetQuestionnaires Nederland BV, 2005]) which have proposed some general guidelines to be followed in the process of developing questions in order to obtain informative and accurate results. In the next enumeration, these guidelines are described and how this work dealt with them.

1. Indicate the research goal and write a brief introduction. The provision of the research goal and a brief introduction are good ways to give the respondents some background and a frame of reference. It also prepares them for what kind of questions they will be asked. For the online survey, an introduction webpage was included which provides the research goal and a brief introduction about the research topic (see figure 4 below). The hard-copy included the cover letter (see Appendix A).

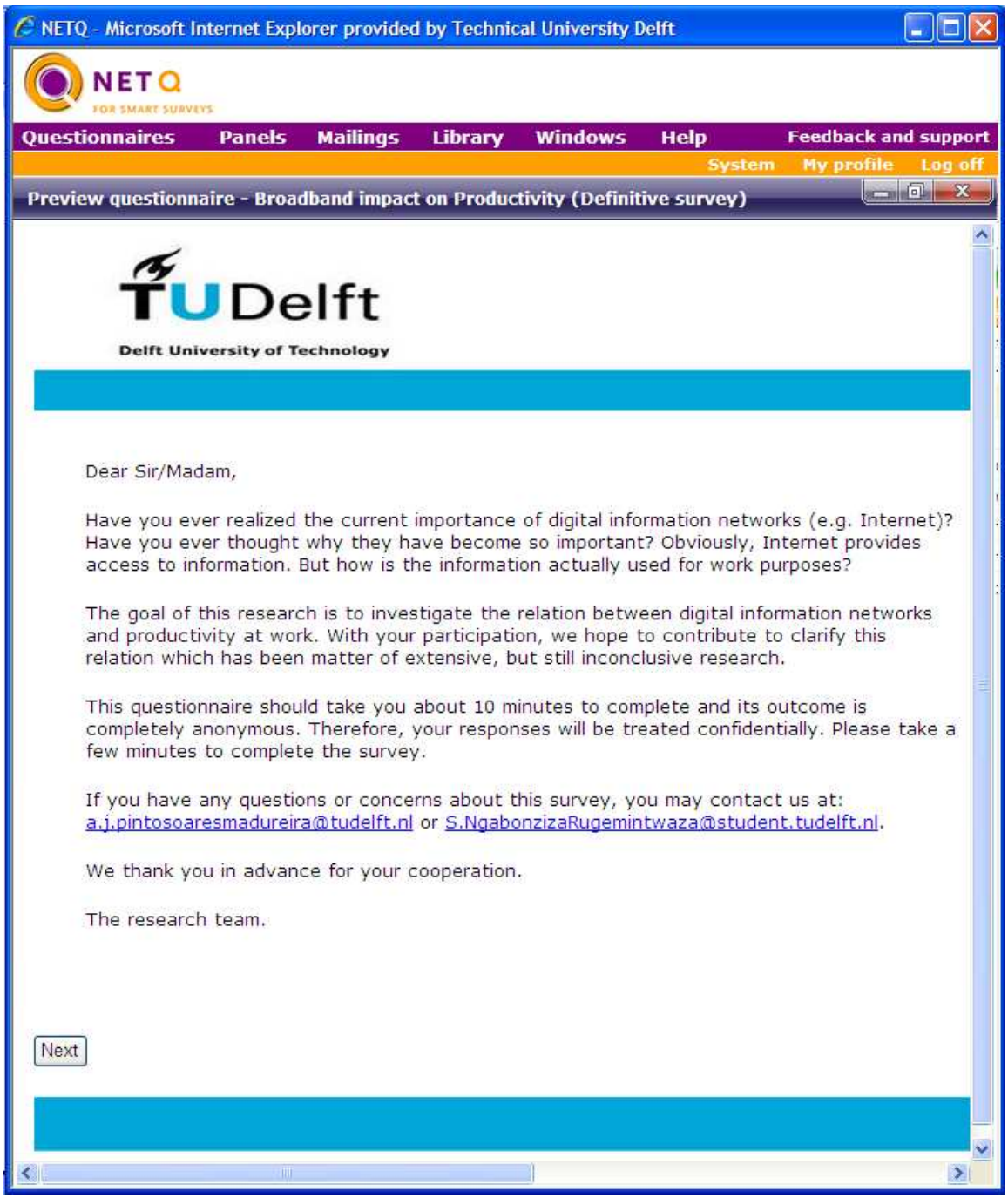


Figure 4: An introduction webpage

2. Select your target group. This group is often called the 'target population'. Correctly determining the target population is critical. Therefore, it is important to know what kind of people the survey aims. If the right target is not selected, the goals are not achieved. In the case of this work, people from different economic sectors (e.g. education, transport, agriculture, health care, etc.) using digital information networks and broadband communication were targeted.

3. Begin the survey with interesting questions. Interesting questions will inspire participants to keep reading and complete the survey. The questionnaire started with the capabilities that are often used by people (e.g. trustability) and ended with questions on less tangible capabilities (e.g. hierarchity).

4. Keep the survey brief. The survey should be as short as possible. Thus, the questions made were specific and only the strictly necessary. The questionnaire contained about 12 questions, some of which contained multiple items.

5. Use simple language and common concepts. The use of proper wording of a question is very important, otherwise there is the risk that respondents may interpret the question differently to that intended by the researcher. Some terminologies (such as digital information networks and broadband) seem not to be commonly recognizable. Before introducing the questions, important definitions were given (see Appendix B).

6. Ensure that the questions flow. Grouping the questions into clear categories makes the task of completing the survey easier for the participants. Participants think some questions are similar when they are not properly arranged. The questions that could have such impact were put together in the questionnaire. In this way the respondents could easily identify their relatedness (e.g. coordinativity and cooperativity).

7. Ask personal fact questions. Respondents prefer to answer questions of personal fact than questions of general opinion. For each capability, practical examples were given (e.g. sharing information using websites like Facebook) to make the questions more concrete.

8. Ask multiple choice questions on important questions. For all the questions related with the Trans model it is given to the respondents multiple choices (*completely, mostly, occasionally, slightly, not at all, and can not answer* (e.g. see figure 5 below)) dependent on the extent that the interviewee agrees with a given statement. The goal is not to have a precise impression from the interviewee, but only a general perception. The process of analyzing data also becomes easier. Open questions were only used as optional, where it was necessary to have additional information (e.g. about the clarity of the questions).

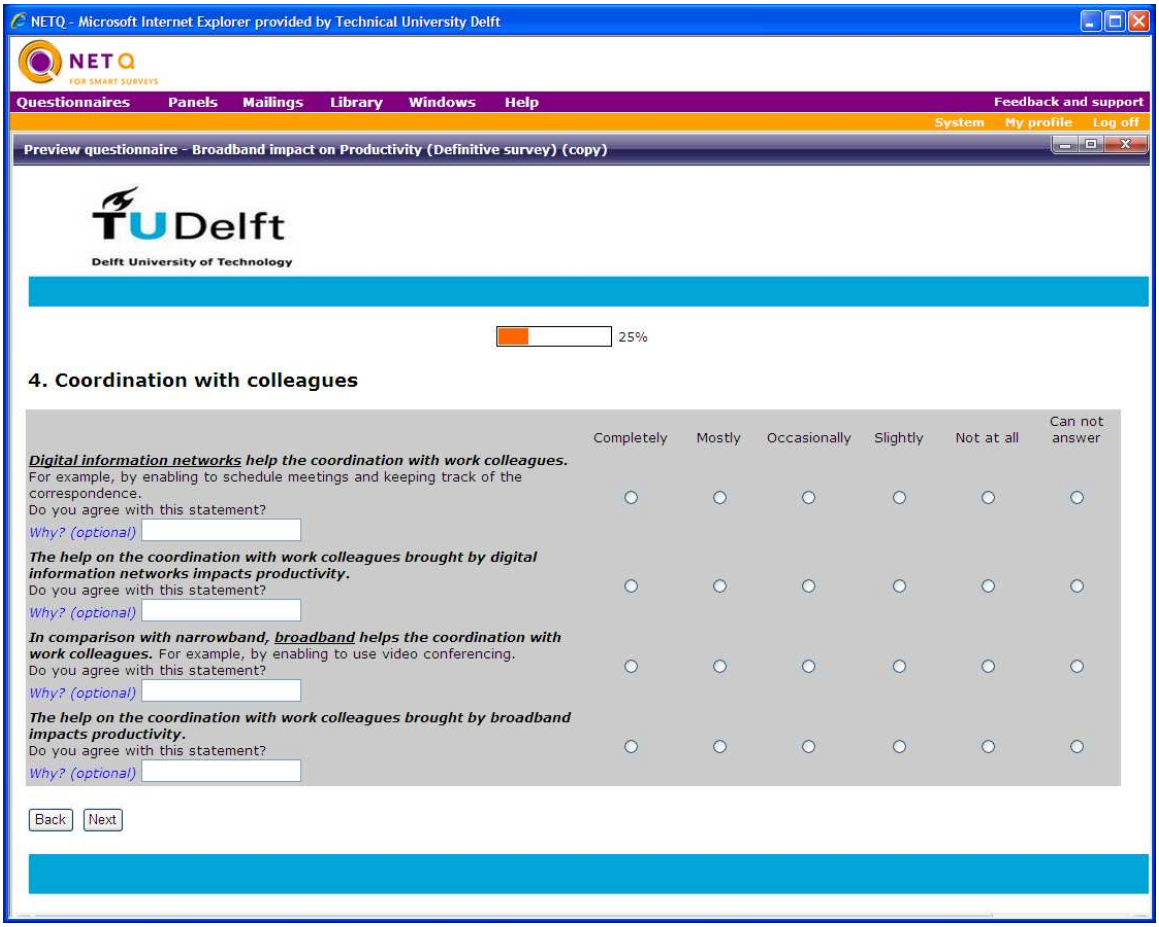


Figure 5: Multiple choice questions

9. Avoid participants responding multiple times. Some people can respond several times to the questionnaire, particularly in the case of the online survey. This action can bias the results. NetQuestionnaires survey tool provides the possibility to allow the participants to complete the online survey exactly once.

10. Remember to say thank you. To complete the survey, respondents need to invest their time and should be thanked either in a covering letter, at the end of completing the survey or in a follow up letter. In the last page of the questionnaire (see figure 6), a message is included of thanks to the respondents for their cooperation.

Figure 6: The end webpage

The questions enumerated below were used in the questionnaire. The complete structure of the questionnaire and details of the order of the questions used in the survey is given in Appendix B.

1. Sensitivity

   - In comparison with traditional forms of information transfer (e.g. newspapers and letters), digital information networks change the way information is experienced. For example, by providing a more pleasant experience using animated and interactive content, instead of a static sheet of paper. Do you agree with this statement?

   - The change brought by digital information networks to the way information is experienced impacts productivity. Do you agree with this statement?

   - In comparison with narrowband, broadband changes the way information is experienced. For example, by providing animated instead of text-based content. Do you agree with this statement?

   - The change brought by broadband to the way information is experienced impacts productivity. Do you agree with this statement?

2. Trustability

   - Digital information networks impact the entrustment with work colleagues. For example, by enabling to share affective information using websites like Facebook. Do you agree with this statement?

   - The impact to the entrustment with work colleagues brought by digital information networks impacts, at a longer term, productivity. Do you agree with this statement?

   - In comparison with narrowband, broadband impacts the entrustment with work colleagues. For example, by enabling to share in-group day-out videos. Do you agree with this statement?

   - The impact to the entrustment with work colleagues brought by broadband impacts, at a longer term, productivity. Do you agree with this statement?

3. Hierarchity

   - An organization usually has a formal hierarchy (CEO, managers, technicians, etc). But often, in practice, hierarchies are ineffective due to lack of communication between members of the hierarchy. Digital information networks change the effectiveness of hierarchies by facilitating the communication between its members. Do you agree with this statement?

   - The impact on the hierarchical structure of an organization brought by digital information networks impacts, at a longer term, productivity. Do you agree with this statement?

   - In comparison with narrowband, broadband changes the effectiveness of hierarchies by facilitating the communication between its members. Do you agree with this statement?

   - The impact on the hierarchical structure of an organization brought by broadband impacts, at a longer term, productivity. Do you agree with this statement?

4. Normativity

   - Digital information networks impact the adoption or fulfillment of norms, conventions or rules within an organization. For example, with regular email advertisement of good examples of loyalty to the organization. Do you agree with this statement?

   - The impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by digital information networks impacts, at a longer term, productivity. Do you agree with this statement?

   - In comparison with narrowband, broadband impacts the adoption or fulfillment of norms, conventions or rules within an organization. For example, with regular video conferences by the CEO about organizational values. Do you agree with this statement?

- The impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by broadband impacts, at a longer term, productivity. Do you agree with this statement?

5. Coordinativity

- Digital information networks help the coordination with work colleagues. For example, by enabling to schedule meetings and keeping track of the correspondence. Do you agree with this statement?
- The help on the coordination with work colleagues brought by digital information networks impacts productivity. Do you agree with this statement?
- In comparison with narrowband, broadband helps the coordination with work colleagues. For example, by enabling to use video conferencing. Do you agree with this statement?
- The help on the coordination with work colleagues brought by broadband impacts productivity. Do you agree with this statement?

6. Cooperativity

- Digital information networks help to find cooperation opportunities with other parties. For example, finding business partners, providers of the inputs required by a company or consumers of the products or services delivered by a company. Do you agree with this statement?
- The help on finding cooperation opportunities brought by digital information networks impacts productivity. Do you agree with this statement?
- In comparison with narrowband, broadband helps to find cooperation opportunities with other parties. For example, by using attractive content for marketing products or services to consumers. Do you agree with this statement?
- The help on finding cooperation opportunities brought by broadband impacts productivity. Do you agree with this statement?

7. Adoptativity

- Digital information networks help to acquire novel knowledge. For example, by having online trainings or accessing digital libraries. Do you agree with this statement?
- The help on acquiring novel knowledge brought by digital information networks impacts productivity. Do you agree with this statement?
- In comparison with narrowband, broadband helps to acquire novel knowledge. For example, by enabling you to download large digital documents. Do you agree with this statement?
- The help on acquiring novel knowledge brought by broadband impacts productivity. Do you agree with this statement?

8. Creativity

   - Digital information networks help to become more creative. For example, by facilitating the access to information from other areas which inspire creative work (like accessing information from another department via network). Do you agree with this statement?
   - The help on becoming more creative brought by digital information networks impacts, at a longer term, productivity. Do you agree with this statement?
   - In comparison with narrowband, broadband helps to become more creative. For example, by enabling to express your creative creations using richer forms of content. Do you agree with this statement?
   - The help on becoming more creative brought by broadband impacts, at a longer term, productivity. Do you agree with this statement?

9. Selectivity

   - Digital information networks help the selection of information. For example, by enabling to make fast selection using search engines such as Google. Do you agree with this statement?
   - The help on the selection of information brought by digital information networks impacts productivity. Do you agree with this statement?
   - In comparison with narrowband, broadband helps the selection of information. For example, providing the outcome of the selection process using rich content (animated images, videos, audio). Do you agree with this statement?
   - The help on the selection of information brought by broadband impacts productivity. Do you agree with this statement?

10. Negotiability

    - Digital information networks help to negotiate prices for products or services. For example, in stock trading sites or second hand online markets such as eBay. Do you agree with this statement?
    - The help on the negotiation of prices brought by digital information networks impacts productivity. Do you agree with this statement?
    - In comparison with narrowband, broadband helps the negotiation of prices for products or services. For example, providing accurate and real time information about stock markets (like with streaming video or audio). Do you agree with this statement?
    - The help on the negotiation of prices brought by broadband impacts productivity. Do you agree with this statement?

11. Economic sector

- In which of the following economic sectors are you active? (see a list of the economic sectors in Appendix B)

12. Completeness of the model

- In the previous questions, we requested your evaluation about the impact of digital information networks and broadband, in particular, on the following aspects: 1) Information is experienced; 2) Entrustment with colleagues; 3) Effective hierarchical operation of an organization; 4) Adoption or fulfillment of norms, conventions or rules; 5) Coordination with colleagues; 6) Cooperation with colleagues; 7) Selection of information; 8) Negotiation of prices for products or services; 9) Adoption of novel knowledge; 10) Creativity at work. If you can remember any other aspect impacted by digital information networks that might have an effect upon your productivity, please specify it below.

5.2 Survey test

The last step in designing the survey is to test the questionnaire and the online tool with a relevant number of respondents. A survey test run can reveal unanticipated problems with the clarity of the questions (see [Creative research systems, 2007]). In this respect, useful feedback from the respondents can be received to redesign the questionnaire. Furthermore, it can already provide indicative results about the main purpose of this work: investigate the impact of broadband to organizational productivity. One report suggests that the test population should be at least 5-8 respondents (see [Tim, 2008]). Another report noted that this group should be between 25 and 75 persons (see [Alix, 2008]). In total, the questionnaire was tested with 69 people (50 people for the hard-copy delivery method and 19 people for the online survey). For the hard-copy delivery approach, a first round of 10 deliveries was made. Looking at this first sample, and particularly at the questions that got a high replying rate of 'can not answer' option, enabled to improve the questionnaire. This same exercise was repeated progressively until five rounds were reached. That is, up to 50 people and then the online version was published. With the online version, replies were gathered.

5.3 Results of the survey test

In this section, a detailed analysis of the findings obtained in the test of the questionnaire is provided. Out of 110 people contacted to complete the survey, actually 63% or 69 people did. Therefore, it is a limited number of respondents, but for a test purpose this number is acceptable.

Nevertheless, it is important to highlight the background of our respondents. The respondents who replied to the survey are originally from different economic sectors (amusement and recreation, construction, education, energy, environmental care, finance, industry, telecommunication, tourism, transport, etc). Some respondents indicated that they are active in only one sector, while others indicated that they are active in more than one. A few respondents filled out the survey anonymously, so their economic sectors could not be traced.

In the next subsection, the findings of the survey test are analyzed for each capability identified in the Trans model. For this analysis, the following grading system (completely-5, mostly-4, occasionally-3, slightly-2, not at all-1, and can not answer-0) was used.

5.3.1 Sensitivity

In comparison with traditional forms of information transfer, digital information networks and broadband change the way information is experienced. This view is shared by *81%* of respondents, which opted in favour of the answers *mostly* and *completely*.

26% hold the opinion that the change brought by digital information networks to the way information is experienced has an impact on productivity only *occasionally*. *62%* opted in favour of the answers *mostly* and *completely*.

80% of the respondents hold the opinion that broadband, in comparison with narrowband, changes the way information is experienced, opting for the answers *mostly* and *completely*.

67% agree that the change on the way information is experienced enabled by broadband has an impact on productivity, opting for *mostly* and *completely*. *23%* hold the opinion that it is only *occasionally*. The results are shown in table 2 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
In comparison with traditional forms of information transfer (e.g. newspapers and letters), digital information networks change the way information is experienced.	0.0	1.4	4.3	13.0	37.7	43.5	4.17	0.80
The change brought by digital information networks to the way information is experienced impacts productivity.	0.0	1.4	10.1	26.1	34.8	27.5	3.77	1.13
In comparison with narrowband, broadband changes the way information is experienced.	0.0	1.4	4.3	14.5	40.6	39.1	4.12	0.84
The change brought by broadband to the way information is experienced impacts productivity.	0.0	1.4	8.7	23.2	37.7	29.0	3.84	1.09

Table 2: Sensitivity

5.3.2 Trustability

Digital information networks impact the entrustment with work colleagues. This view is shared by *48%* of respondents, which opted in favour of the answers *mostly* and *completely*. *41%* hold the opinion that it is only *occasionally*.

51% consider the entrustment with work colleagues brought by digital information networks to have an impact on productivity, opting for the answers *mostly* and *completely*. *33%* hold the opinion that it is only *occasionally*.

57% opted in favour of *mostly* and *completely*, concerning the impact of broadband to the entrustment between work colleagues. *29%* hold the opinion that it is only *occasionally*.

59% hold the opinion that the entrustment with work colleagues brought by broadband has an impact on productivity, opting for the answers *mostly* and *completely*. *20%* hold the opinion that it is only *occasionally*.

1% of the respondents *can not answer* all the questions. The results are shown in table 3 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks impact the entrustment with work colleagues.	0.0	2.9	8.7	40.6	34.8	13.0	3.46	0.86
The impact to the entrustment with work colleagues brought by digital information networks impacts, at a longer term, productivity.	0.0	5.8	10.1	33.3	31.9	18.8	3.48	1.18
In comparison with narrowband, broadband impacts the entrustment with work colleagues.	1.4	4.3	8.7	29.0	33.3	23.2	3.58	1.13
The impact to the entrustment with work colleagues brought by broadband impacts, at a longer term, productivity.	0.0	5.8	14.5	20.3	40.6	18.8	3.52	1.26

Table 3: Trustability

5.3.3 Normativity

Digital information networks have impact on the adoption or fulfillment of norms, conventions or rules within an organization. *55%* of our sample agrees with this statement, opting in favour of *mostly* and *completely*. *23%* hold the opinion that it is only *occasionally*.

46% hold the opinion that the impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by digital information networks *mostly* has an impact on productivity. *39%* hold the opinion that it is only *occasionally*.

When asked if broadband, in comparison with narrowband, impacts the adoption or fulfillment of norms, conventions or rules within an organization by making use of videoconferencing, one respondent noted that: *"visual presentation has a better impact on human psyche"*. Indeed, this might be the general case but the point of this question was to check it particularly for normativity. *51%* of the respondents hold the opinion that broadband, in comparison with narrowband, impacts the adoption or fulfillment of norms, conventions or rules within an organization, opting for the answers *mostly* and *completely*. *26%* hold the opinion that it is only *occasionally*.

59% agree that the impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by broadband has an impact on productivity, opting for *mostly* and *completely*. *26%* hold the opinion that it is only *occasionally*.

3% of the respondents *can not answer* all the questions. The results are shown in table 4 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks impact the adoption or fulfillment of norms, conventions or rules within an organization.	2.9	2.9	15.9	23.2	37.7	17.4	3.42	1.60
The impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by digital information networks impacts, at a longer term, productivity.	1.4	2.9	4.3	39.1	46.4	5.8	3.43	1.62
In comparison with narrowband, broadband impacts the adoption or fulfillment of norms, conventions or rules within an organization.	2.9	4.3	15.9	26.1	37.7	13.0	3.30	1.79
The impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by broadband impacts, at a longer term, productivity.	2.9	5.8	5.8	26.1	44.9	14.5	3.48	1.71

Table 4: Normativity

5.3.4 Hierarchity

Digital information networks change the effectiveness of hierarchies by facilitating the communication between its members. This opinion is shared by *61%* of the respondents, opting in favour of the answers *mostly* and *completely* and *20%* opt that this is only *occasionally*.

64% of the respondents hold the opinion that the change brought by digital information networks to the effectiveness of hierarchies has an impact on productivity, opting for *mostly* and *completely*. *22%* hold the opinion that it is only *occasionally*.

55% hold the opinion that broadband, in comparison with narrowband, changes the effectiveness of hierarchies, opting for *mostly* and *completely*. *23%* opted for *occasionally*.

57% hold the opinion that the change in the hierarchical structure of an organization brought by broadband impacts productivity, opting for *mostly* and *completely*. *23%* hold the opinion that it is only *occasionally*. *4%* of respondents *can not answer* all the questions. The results are shown in table 5 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks change the effectiveness of hierarchies by facilitating the communication between its members.	2.9	4.3	11.6	20.3	36.2	24.6	3.57	1.45
The impact on the hierarchical structure of an organization brought by digital information networks impacts, at a longer term, productivity.	2.9	4.3	7.2	21.7	46.4	17.4	3.57	1.58
In comparison with narrowband, broadband changes the effectiveness of hierarchies by facilitating the communication between its members.	1.4	4.3	15.9	23.2	36.2	18.8	3.45	1.62
The impact on the hierarchical structure of an organization brought by broadband impacts, at a longer term, productivity.	4.3	4.3	11.6	23.2	37.7	18.8	3.42	1.60

Table 5: Hierarchity

5.3.5 Coordinativity

One of the most convincing results is found on coordinativity. *Digital information networks help on the coordination with work colleagues. 84%* opted in favour of *mostly* and *completely.*

The help on the coordination brought by digital information networks has an impact on productivity. This opinion is shared by *80%* of the respondents opting in favour of the answers *mostly* and *completely.* One respondent reveal his experience with digital information networks and note that *"the company where I was working before used to be huge, and only networking would help somehow filtrate the information and coordinate job with colleagues from different departments".*

72% of the respondents opt in favour of *mostly* and *completely*, concerning broadband.

For this case, *70%* agree that the help on the coordination with work colleagues brought by broadband impacts productivity, opting for *mostly* and *completely.* The results are shown in table 6 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks help the coordination with work colleagues.	0.0	0.0	7.2	8.7	37.7	46.4	4.23	0.74
The help on the coordination with work colleagues brought by digital information networks impacts productivity.	0.0	1.4	1.4	17.4	42.0	37.7	4.13	0.75
In comparison with narrowband, broadband helps the coordination with work colleagues.	0.0	1.4	5.8	20.3	44.9	27.5	3.91	1.04
The help on the coordination with work colleagues brought by broadband impacts productivity.	0.0	1.4	5.8	23.2	37.7	31.9	3.93	0.97

Table 6: Coordinativity

5.3.6 Cooperativity

On cooperativity we find also other persuasive results. *Digital information networks help to find cooperation opportunities with other parties. 81%* opted in favour of *mostly* and *completely*.

The help on finding cooperation opportunities brought by digital information networks has an impact on productivity. This opinion is shared by *77%* of the respondents opting in favour of the answers *mostly* and *completely*.

78% believe that broadband, in comparison with narrowband, helps to find cooperation opportunities with other parties.

For this case, *74%* agree that the cooperation opportunities brought by broadband impacts productivity, opting for *mostly* and *completely*. The results are shown in table 7 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks help to find cooperation opportunities with other parties.	0.0	0.0	5.8	13.0	44.9	36.2	4.12	0.78
The help on finding cooperation opportunities brought by digital information networks impacts productivity.	0.0	2.9	4.3	15.9	43.5	33.3	4.00	1.03
In comparison with narrowband, broadband helps to find cooperation opportunities with other parties.	0.0	1.4	1.4	18.8	50.7	27.5	4.01	0.88
The help on finding cooperation opportunities brought by broadband impacts productivity.	0.0	2.9	1.4	21.7	44.9	29.0	3.96	1.00

Table 7: Cooperativity

5.3.7 Selectivity

Digital information networks help the selection of information. This opinion is shared by *83%* of the respondents, opting in favour of the answers *mostly* and *completely*.

75% hold the opinion that the help on the selection of information brought by digital information networks impacts productivity, opting for *mostly* and *completely*.

71% of the respondents agree that broadband, in comparison with narrowband, helps the selection of information.

74% opted in favour of the answers *mostly* and *completely*, the selection of information brought by broadband impacts productivity and *19%* hold the opinion that this is only *occasionally*. The results are shown in table 8 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks help the selection of information.	0.0	0.0	4.3	13.0	30.4	52.2	4.30	0.63
The help on the selection of information brought by digital information networks impacts productivity.	0.0	2.9	4.3	17.4	39.1	36.2	4.01	1.00
In comparison with narrowband, broadband helps the selection of information.	2.9	2.9	4.3	18.8	40.6	30.4	3.83	1.08
The help on the selection of information brought by broadband impacts productivity.	1.4	4.3	1.4	18.8	39.1	34.8	3.94	1.04

Table 8: Selectivity

5.3.8 Negotiability

Digital information networks help to negotiate prices for products or services. 58% of the respondents agree with this statement, opting in favour of the answers *mostly* and *completely*.

55% share the opinion that the help on the negotiation of prices brought by digital information networks has an impact on productivity, opting in favour of *mostly* and *completely*. *30%* opted for *occasionally*.

54% of the respondents hold the opinion that broadband, in comparison with narrowband, helps the negotiation of prices for products or services, opting for the answers *mostly* and *completely*.

49% agree that the help on the negotiation of prices enabled by broadband has an impact on productivity, opting for *mostly* and *completely*. *32%* opted for *occasionally*.

6% of the respondents *can not answer* all the questions. The results are shown in table 9 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks help to negotiate prices for products or services.	4.3	1.4	5.8	30.4	39.1	18.8	3.55	1.23
The help on the negotiation of prices brought by digital information networks impacts productivity.	5.8	4.3	4.3	30.4	39.1	15.9	3.41	1.52
In comparison with narrowband, broadband helps the negotiation of prices for products or services.	2.9	4.3	14.5	24.6	36.2	17.4	3.39	1.64
The help on the negotiation of prices brought by broadband impacts productivity.	5.8	2.9	11.6	31.9	33.3	14.5	3.28	1.53

Table 9: Negotiability

5.3.9 Adoptativity

Digital information networks help to acquire novel knowledge. 75% of the respondents agree with this statement, opting in favour of the answers *mostly* and *completely*.

74% hold the opinion that the help on acquiring novel knowledge brought by digital information networks has an impact on productivity, opting for *mostly* and *completely*.

81% opted in favour of *mostly* and *completely*, concerning the impact of broadband to acquire novel knowledge. One respondent find broadband with high potential to download large digital documents and reported that: *"more knowledge can be gathered in less time with broadband networks"*.

75% agree that the help on acquiring novel knowledge enabled by broadband has an impact on productivity, opting for *mostly* and *completely*. *1%* of the respondents *can not answer* all the questions. The results are shown in table 10 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks help to acquire novel knowledge.	0.0	0.0	2.9	21.7	29.0	46.4	4.19	0.65
The help on acquiring novel knowledge brought by digital information networks impacts productivity.	0.0	1.4	5.8	18.8	34.8	39.1	4.04	0.90
In comparison with narrowband, broadband helps to acquire novel knowledge.	1.4	0.0	2.9	14.5	43.5	37.7	4.12	0.66
The help on acquiring novel knowledge brought by broadband impacts productivity.	1.4	1.4	2.9	18.8	43.5	31.9	3.97	0.88

Table 10: Adoptativity

5.3.10 Creativity

Digital information networks help to become more creative. This opinion is shared by *61%* of the respondents, opting in favour of the answers *mostly* and *completely* and *29%* opt that this is only *occasionally*.

67% hold the opinion that the help on becoming more creative brought by digital information networks has an impact on productivity, opting for *mostly* and *completely*.

64% agree that broadband in comparison with narrowband, helps to become more creative, opting for *mostly* and *completely*. *22%* hold the opinion that it is only *occasionally*.

61% opted in favour of *mostly* and *completely*, the help on becoming more creative enabled by broadband has an impact on productivity.

6% of the respondents *can not answer* all the questions. The results are shown in table 11 below.

% of respondents, N=69								
	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Digital information networks help to become more creative.	0.0	4.3	5.8	29.0	31.9	29.0	3.75	1.19
The help on becoming more creative brought by digital information networks impacts, at a longer term, productivity.	5.8	1.4	7.2	18.8	42.0	24.6	3.64	1.21
In comparison with narrowband, broadband helps to become more creative.	2.9	1.4	10.1	21.7	36.2	27.5	3.70	1.15
The help on becoming more creative brought by broadband impacts, at a longer term, productivity.	5.8	4.3	13.0	15.9	40.6	20.3	3.42	1.69

Table 11: Creativity

Tables 12, 13, 14, 15 below resume the results obtained.

	% of respondents, N=69							
Capabilities	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Sensitivity	0.0	1.4	4.3	13.0	37.7	43.5	4.17	0.80
Trustability	0.0	2.9	8.7	40.6	34.8	13.0	3.46	0.86
Normativity	2.9	2.9	15.9	23.2	37.7	17.4	3.42	1.60
Hierarchity	2.9	4.3	11.6	20.3	36.2	24.6	3.57	1.45
Coordinativity	0.0	0.0	7.2	8.7	37.7	46.4	4.23	0.74
Cooperativity	0.0	0.0	5.8	13.0	44.9	36.2	4.12	0.78
Selectivity	0.0	0.0	4.3	13.0	30.4	52.2	4.30	0.63
Negotiability	4.3	1.4	5.8	30.4	39.1	18.8	3.55	1.23
Adoptativity	0.0	0.0	2.9	21.7	29.0	46.4	4.19	0.65
Creativity	0.0	4.3	5.8	29.0	31.9	29.0	3.75	1.19

Table 12: The relevance of DINs for the capabilities identified in the Trans model.

	% of respondents, N=69							
Capabilities	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Sensitivity	0.0	1.4	10.1	26.1	34.8	27.5	3.77	1.13
Trustability	0.0	5.8	10.1	33.3	31.9	18.8	3.48	1.18
Normativity	1.4	2.9	4.3	39.1	46.4	5.8	3.43	1.62
Hierarchity	2.9	4.3	7.2	21.7	46.4	17.4	3.57	1.58
Coordinativity	0.0	1.4	1.4	17.4	42.0	37.7	4.13	0.75
Cooperativity	0.0	2.9	4.3	15.9	43.5	33.3	4.00	1.03
Selectivity	0.0	2.9	4.3	17.4	39.1	36.2	4.01	1.00
Negotiability	5.8	4.3	4.3	30.4	39.1	15.9	3.41	1.52
Adoptativity	0.0	1.4	5.8	18.8	34.8	39.1	4.04	0.90
Creativity	5.8	1.4	7.2	18.8	42.0	24.6	3.64	1.21

Table 13: The relevance of the capabilities brought by DINs for productivity.

	% of respondents, N=69							
Capabilities	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Sensitivity	0.0	1.4	4.3	14.5	40.6	39.1	4.12	0.84
Trustability	1.4	4.3	8.7	29.0	33.3	23.2	3.58	1.13
Normativity	2.9	4.3	15.9	26.1	37.7	13.0	3.30	1.79
Hierarchity	1.4	4.3	15.9	23.2	36.2	18.8	3.45	1.62
Coordinativity	0.0	1.4	5.8	20.3	44.9	27.5	3.91	1.04
Cooperativity	0.0	1.4	1.4	18.8	50.7	27.5	4.01	0.88
Selectivity	2.9	2.9	4.3	18.8	40.6	30.4	3.83	1.08
Negotiability	2.9	4.3	14.5	24.6	36.2	17.4	3.39	1.64
Adoptativity	1.4	0.0	2.9	14.5	43.5	37.7	4.12	0.66
Creativity	2.9	1.4	10.1	21.7	36.2	27.5	3.70	1.15

Table 14: In comparison with narrowband, the relevance of broadband for the capabilities identified in the Trans model.

% of respondents, N=69								
Capabilities	Can not answer	Not at all	Slightly	Occasionally	Mostly	Completely	Mean	Std. dev
Sensitivity	0.0	1.4	8.7	23.2	37.7	29.0	3.84	1.09
Trustability	0.0	5.8	14.5	20.3	40.6	18.8	3.52	1.26
Normativity	2.9	5.8	5.8	26.1	44.9	14.5	3.48	1.71
Hierarchity	4.3	4.3	11.6	23.2	37.7	18.8	3.42	1.60
Coordinativity	0.0	1.4	5.8	23.2	37.7	31.9	3.93	0.97
Cooperativity	0.0	2.9	1.4	21.7	44.9	29.0	3.96	1.00
Selectivity	1.4	4.3	1.4	18.8	39.1	34.8	3.94	1.04
Negotiability	5.8	2.9	11.6	31.9	33.3	14.5	3.28	1.53
Adoptativity	1.4	1.4	2.9	18.8	43.5	31.9	3.97	0.88
Creativity	5.8	4.3	13.0	15.9	40.6	20.3	3.42	1.69

Table 15: The relevance of the capabilities brought by broadband for productivity.

5.4 Discussion and conclusion

In this chapter, the development of the questionnaire was done using the Trans model. Based on this questionnaire, a survey was conducted to a relevant population to test the clarity of the questionnaire, to test the impact of broadband and digital information networks to organizational productivity, and to test the completeness of the Trans model.

To test the clarity of the questions, the option 'can not answer' was used in the questionnaire as an indicator. This indicator enabled to identify the questions which can not be understood by the respondents. Questions which got a high replying rate of 'can not answer' option were re-designed and the questionnaire was tested again every time there was changes done. From this exercise, the relevant feedback received from the respondents helped to improve some questions of the questionnaire.

Despite the effort made in the process of improving the questionnaire, some questions on certain capabilities remained still unclear to respondents. These questions should be redesigned in the future work to improve this questionnaire. Moreover, some respondents gave an elaborated opinion about their clarity of the questions. One respondent noted that *"some of the questions are hard to understand and could be written in more 'straight forward' English. For people whose English is not their first language, this is really a difficult task. You have to keep questions simple as white is white and black is black". If you would give this kind of questions, then people would answer as they like, but not with fully understanding the meaning of the questions".*

Referring to the results (summarized in tables 12, 13, 14 and 15 above), looking at the indicator 'can not answer' option, it is observed that there are more unclear questions on broadband compared to DINs. For DINs, four capabilities (normativity, hierarchity, negotiability, and creativity) have this indicator (see tables 12 and 13 above). For broadband, seven capabilities (trustability, normativity, hierarchity, selectivity, negotiability, adoptativity, and creativity) are identified with this indicator (see tables 14 and 15 above). Both DINs and broadband have two capabilities (negotiability and creativity) which were identified with a very high replying rate of 'can not answer' (see tables 13 and 15 above). Therefore, from these results, it is

difficult to take any preliminary conclusion about the importance of broadband for these capabilities. On the other hand, the results on some capabilities (sensitivity, coordinativity, cooperativity, and adoptativity) are very interesting, they seem to be clear and have a low standard deviations.

Concerning the impact of DINs and broadband to organizational productivity, these tables show that the mean values of the DINs are similar to the mean values obtained for broadband. This serves as an indication that people are conscientious with the impact of the digital information networks and broadband on their productivity, but are not able to distinguish broadband from narrowband. For instance, from the interview conducted, different respondents repeatedly said that they found a lot of similarities in the questions. Symptomatically, one of them noted: *"It should be more simply... I think... a lot of questions look the same"*. Therefore, a thorough redesign of this questionnaire is required. The relevant results are resumed in figure 7 below. It is worth to mention that the results on some capabilities are interesting and can already give a good impression of the future outcomes. In general, the following capabilities (sensitivity, coordinativity, cooperativity, selectivity, and adoptativity) seem to be more important for the economic agent' productivity. They have high mean values and low standard deviations compared to other capabilities. The results on the other capabilities (trustability, normativity, hierarchity, negotiability, and creativity) are not trustable due to the perceived unclarity of the questions to some respondents. This perception is observed for both DINs and broadband cases.

In this chapter, it was also investigated the completeness of the Trans model by asking the respondents *"if they can remember any other aspect impacted by digital information networks that might have an effect upon their productivity"*. From the feedback received from respondents, there was no new capability identified. All the proposed impacts were carefully analyzed and found to be covered within the already identified capabilities. For example, some respondents noted that "digital information network enables communication in general, effective time management, and knowledge sharing by allowing effective distribution of products to an audience such as a publication". These impacts were classified under the capabilities (trustability, coordinativity, and adoptativity) respectively, already identified in the Trans model. Therefore, from these observations, it seems that the Trans model is complete. Future work should continue to investigate this point as the knowledge on broadband is growing and the impact of broadband to organizational productivity is continuing to spread.

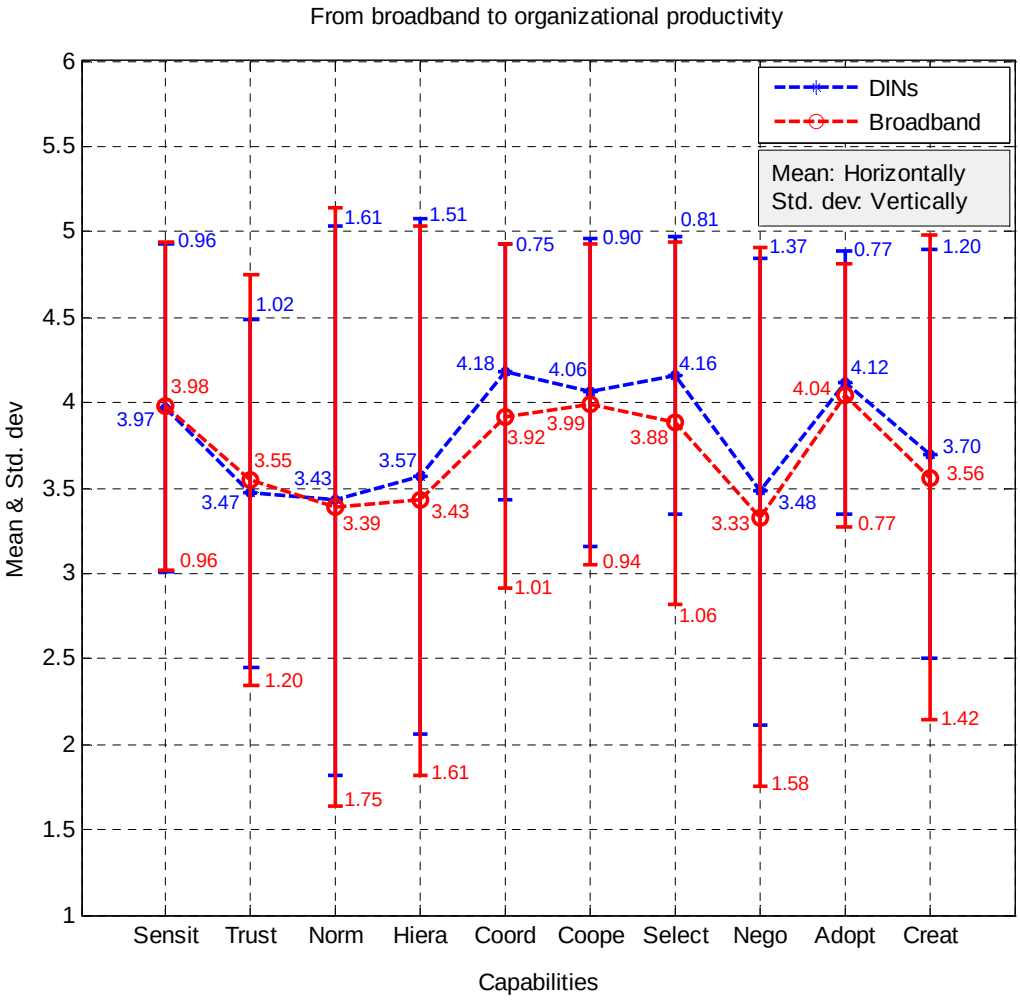


Figure 7: Resume of the impact of broadband and DINs to organizational productivity

Finally, the important conclusion that can be taken from these results of this survey (summarized in figure 7 above) is that the majority of the interviewees are conscientious of the impact of the digital information networks and broadband on their productivity, but are not able to distinguish broadband from narrowband. In general, they don't care about the types of networks they are using as long as they can do their job. From these results, it is observed that the capabilities (sensitivity, coordinativity, cooperativity, selectivity, and adoptativity) have interesting results, they seem to be more important for the economic agent' productivity, they have high mean values and low standard deviations. The results on the other capabilities (trustability, normativity, hierarchity, negotiability, and creativity) are the opposite; they have low mean values and high standard deviations. Another important observation is that generally, the mean values of all the capabilities) for broadband are lower compared to DINs, except for one capability (normativity) where it is the inverse. This unexpected observation might be due to the perceived unclarity of the questions to the majority of the respondents. Therefore, it is difficult at this stage

to take a concrete conclusion about the impact of broadband, since users are not clarified about the difference between broadband and narrowband networks. With a careful re-design of the questions of the questionnaire, this exercise should be able to bring a clear explanation to the interviewees about the difference between these two networks in order to clarify the already perceived relevance of broadband.

Chapter 6

Conclusion and future work

6.1 Conclusion

This thesis contributes to clarify the importance of broadband, by investigating the following research questions: 1) what is the state of the art concerning the impact of broadband to organizational productivity; 2) is there any thorough and generally accepted framework to investigate the relation from broadband to organizational productivity; 3) if not, which framework can be used; 4) how the applicability of such framework can be tested; and 5) which conclusions can be derived about the impact of broadband using this framework?

From a summary of the state of the art, it was noted that there is a considerable excitement about the potential effects of broadband not only on internet use, e-commerce, wealth, entertainment, etc., but also in other economic factors. Broadband investment appears to provide substantial benefits to both consumers and the overall economy. Broadband investment and services appear to stimulate economic output, increase productivity, telecom competition, cost reduction and increase tax revenue as well as create jobs. Despite this general perception, the announced impacts were not yet backed up with factual evidences. Scientifically grounding this perception is an essential input to the development of telecommunication infrastructures related public and private policies.

The theoretical background for this thesis work was laid down in chapter 3. It consists of a causal model, labelled Trans, that underpins the relation between digital information networks and organizational economic productivity. Being broadband a particular case of digital information networks, this thesis work hypothesized that the Trans model would be applicable to investigate the relation between broadband and organizational productivity.

The model has been developed by [Madureira et al., 2009], and it is still in a preliminary stage. At a higher level of detail, Trans identifies capabilities (sensitivity, trustability, hierarchity, normativity, coordinativity, cooperativity, adoptativity, creativity, selectivity, and negotiability) of the economic agent somehow effected by digital information networks. At a lower level of detail, capabilities are structured in layers (sensit, jungit and intelligit). The sensit layer (meaning to sense) encompasses one capability (sensitivity) which enables an agent to sense information. An agent might be sensible to information quality and quantity. The jungit

layer (meaning to join) encompasses the capabilities which enable an agent to establish relationships (trustability, normativity and hierarchity) with other agents. Jungit capabilities' effects in productivity might be positive or negative. From an economic perspective, the function of the agent is to choose and perform between alternative rational capabilities to navigate through the production space problem. These capabilities (adoptativity, creativity, selectivity, negotiability, coordinativity, and cooperativity), identified in the intelligit layer (meaning to think), entitle the economic agent to be in a higher state of productivity.

A set of observations from a thorough literature review done on the relevance of broadband was distilled in chapter 4. By mapping this extensive, but scattered set of observations with the Trans model, the relevant outcomes of broadband were structured in a valid conceptual way. Furthermore, with this exercise it was proven the validity of the Trans model to investigate the impact of broadband to organizational productivity.

A questionnaire was developed in chapter 5 to evaluate the impact of broadband and digital information networks to organizational productivity. This questionnaire was designed based upon the Trans model. Based on this questionnaire, a survey was done to a relevant population to test the clarity of the questionnaire, to test the impact of broadband and digital information networks to organizational productivity, and to test the completeness of the Trans model. Two methods were used to deploy the survey: hard-copy delivery and online webpage.

Concerning the clarity of the survey's questions, some questions on certain capabilities were not clear to some respondents. The indicator 'can not answer' option was used to test the clarity of the questions. For digital information networks, four capabilities (normativity, hierarchity, negotiability, and creativity) were identified with this indicator. For the case of broadband, seven capabilities (trustability, normativity, hierarchity, selectivity, negotiability, adoptativity, and creativity) have this indicator. The respective questions on these capabilities should be carefully re-designed in the future work to improve the questionnaire. Therefore, from these results it is difficult to take any concrete conclusion about the importance of broadband for these capabilities.

From a general observation drawn from the results of the survey, we can conclude that the majority of the interviewees are conscientious of the impact of the digital information networks and broadband on their productivity, but are not able to distinguish broadband from narrowband. In general, they don't care about the types of networks they are using as long as they can do their job. Allied to the unclearness of some questions the results gathered about the impact of broadband to organizational productivity show that the interviewees have difficulties in distinguishing broadband from digital information networks. Thus, it is difficult to take any relevant conclusion in this stage about the impact of broadband. It is worth to mention that the results on some capabilities are interesting and can already give a good impression of the future outcomes. In general, the following capabilities (sensitivity, coordinativity, cooperativity, selectivity, and adoptativity) seem to be more important for the economic agent' productivity. They have a high mean values and low standard deviation compared to other capabilities. The results on the other capabilities (trustability, normativity, hierarchity, negotiability, and creativity) are

not trustable due to the perceived unclarity of the questions to some respondents. This perception is observed to both DINs and broadband cases.

Finally, this work investigated the completeness of the Trans model by asking the respondents "if they can remember any other aspect impacted by digital information networks that might have an effect upon their productivity". From the feedback of the respondents, there was no new capability identified. All the proposed impacts were carefully analyzed and found to be covered within the already identified capabilities. Therefore, from these observations, it seems that the Trans model is complete. However, this should still be investigated in the future work as the knowledge on broadband is still growing and its impact to organizational productivity is continuing to spread.

6.2 Future work

Although the feasibility of the application of the Trans model to investigate the impact of broadband on organizational productivity was proven, the use of the Trans model within an econometric framework is still far. The gap lies in finding representative observational variables for the capabilities described. In practice, an economic agent performing a particular task often uses the capabilities intertwining them together. For example, when negotiating the price of an input, one would expect an agent to select information about prices from other input providers before bidding. Therefore, observational variables have to be found that can be exactly and exclusively associated to each capability.

Secondly, the Trans model addresses the causal relation from digital information networks to micro economic productivity. Thus, it is general enough to cover broadband. But, it does not include specificities uniquely associated to broadband. Therefore, further conceptual work is required to develop the framework to include these specificities, which in the most general sense are allowing digital information related tasks to be done *better* and *faster*.

Despite the effort made in designing the questionnaire, some questions are still unclear. Such questions should be carefully re-designed to improve this questionnaire. Future work should include in the questionnaire clear differences between broadband and general digital information networks to help the respondents to really be able to distinguish them.

From the feedback received from the respondents there was no new capability identified. All the proposed impacts were found to be covered within the already identified capabilities. Still, future work should continue to investigate this point as the knowledge on broadband is growing and the impact of broadband to organizational productivity is continuing to spread.

Further work on this topic should also investigate if there are commonalities between the capabilities of the Trans model, by decomposing these capabilities and test their orthogonality.

Bibliography

[ACG, 2002] ACG, T. (2002). Built For Business II: Beyond Basic Connectivity. Report ordered by Cisco Systems.

[ACG, 2003] ACG, T. (2003). True Broadband- Exploring the economic impacts. An Ericsson contribution to public policy debate.

[ACIL Tasman, 2004] ACIL Tasman (2004). Economic Impacts of Broadband Adoption in Victoria. Technical report, ACIL Tasman.

[Akerlof, 1970] Akerlof, G. (1970). The Market for 'Lemons': Quality Uncertainty and the Market Mechanism. The Quarterly Journal of Economics, 84(3):488-500.

[Alix, 2008] Alix, D. (2008). Guidelines for survey development, ASM BSP research residency.

[Anderson and Raban, 2005] Anderson, B. and Raban, Y. (2005). The Social Impact of Broadband Household Internet Access. Technical Report 2005-06, Chimera Working Paper.

[Annis et al., 2005] Annis, R., McNiven, J., and Curri, M. (2005). Industry Canada Broadband Economic Impact Study Final Report. Technical report, Rural Development Institute, Brandon University.

[AT and T, 2003] AT&T (2003). Remote Working in the Net-Centric Organisation. Technical report, AT&T with the Economist Intelligence Unit.

[Awan, 2005] Awan, A. (2005). Politics, Democracy in the Light of Information and Communication Technology. Communications of the IIMA, 5(4):113-121.

[Balakrishnan et al., 1995] Balakrishnan, A., Kalakota, R., Ow, P., and Whinston, A. (1995). Document-centered information systems to support reactive problem-solving in manufacturing. International Journal of Production Economics, 38(1):31-58.

[Bauer et al., 2002] Bauer, J., Gai, P., Kim, J., Muth, T., and Wildman, S. (2002). Broadband: Benefits and Policy Challenges. Technical report, Quello Center for Merit Network Inc.

[BCC, 2003] BCC (2003). Business Broadband: A BCC Survey, A State of the nation survey into the penetration and impact of broadband on British business, Report compiled and published by the British Chambers of Commerce, September 2003.

[Borges, 1986] Borges, A. (1986). Applied general equilibrium models: an assessment of their usefulness for policy analysis. Technical Report 7, OECD.

[Bourdieu, 1986] Bourdieu, P. (1986). The forms of capital. In Richardson, J., editor, Handbook of theory and research for the sociology of education, pages 241-258. Greenwood Press.

[Brown, 2003] Brown, R. (2003). Social Psychology. Free Press.

[BSG, 2004] BSG (2004). The Impact of Broadband-Enabled ICT, Content, Applications and Services on the UK Economy and Society to 2010. Technical report, Broadband Stakeholder Group.

[Bulkley and Alstyne, 2004] Bulkley, N. and Alstyne, M. V. (2004). Why Information Should Influence Productivity. Working Paper Series 202, MIT Sloan School of Management.

[Burt, 1987] Burt, R. (1987). Social contagion and innovation: Cohesion versus structural equivalence. The American Journal of Sociology, 92(6):1287-1335.

[Caroline and Karen, 2006] Caroline, J. T. and Karen, M. (2006). New Inequality Frontier: Broadband Internet Access. Economic Policy Institute Working Paper No. 275, Kent State University. http://www.epi.org.

[CBS, 2008] CBS (2008). The Digital Economy 2008. Statistics Netherlands.

[CBTF, 2008] CBTF (2008). The State of Connectivity: Building Innovation through Broadband, Final Report of the California Broadband Task Force (rel. Jan. 2008), available at http://www.calink.ca.gov/pdf/CBTF_FINAL _Report.pdf.

[CEBR, 2003] CEBR (2003). The Economic Impact of a Competitive Market for Broadband. Technical report, The Broadband Industry Group.

[Coleman et al., 1966] Coleman, J., Katz, E., and Menzel, H. (1966). Medical Innovation: A Diffusion Study. New York: Bobbs-Merrill.

[Constant et al., 1996] Constant, D., Kiesler, S., and Sproull, L. (1996). The Kindness of Strangers: The Usefulness of Electronic Weak Ties for Technical Advice. Organization Science, 7(2):119-135.

[Crandall et al., 2007] Crandall, R., Lehr,W., and Litan, R. (2007). The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data. Brookings Institution Press.

[Creative research systems, 2007] Creative research systems (2007). "The Survey System." The Survey System Tutorial, July 2006. http://www.surveysystem.com/sdesign.htm.

[Dana, 2008] Dana, F. (2008). 14 Tips for writing an effective Online Survey.

[Davidson and Santorelli, 2008] Davidson, C. and Santorelli, M. (2008). The Impact of Broadband on Senior Citizens, Advanced Communications Law. Technical report, Advanced Communications Law & Policy Institute at New York Law School.

[Decker and Lesser, 1994] Decker, K. and Lesser, V. (1994). Designing a Family of Coordination Algorithms. Technical Report 94-14.

[Diamond, 1989] Diamond, P. (1989). The New Palgrave: Allocation, Information and Markets. In Eatwell, J., Milgate, M., and Newman, P., editors, AAMAS '02: Proceedings of the first international joint conference on Autonomous agents and multiagent systems, pages 191-206. W. W. Norton.

[Dietzenbacher and Lahr, 2004] Dietzenbacher, E. and Lahr, M. (2004). Wassilly Leontief and Input-Output Economics. Cambridge University Press.

[Dosi, 1988] Dosi, G. (1988). Sources, Procedures, and Microeconomic Effects of Innovation. Journal of Economic Literature, 26(3):1120-1171.

[DTI, 2005] DTI (2005). Connecting the UK: the Digital Strategy. Technical report, Prime Minister's Strategy Unit with the Department of Trade and Industry.

[Dwivedi et al., 2008] Dwivedi, Y., Papazafeiropoulou, A., Brinkman, W., and Lal, B. (2008). Examining the influence of service quality and secondary influence on the behavioural intention to change internet service provider. Information Systems Frontiers.

[Ellen, 2002] Ellen, T. P. (2002). Program Development and Evaluation, Survey Procedures, Quick Tips #7, University of Wisconsin-Extension, Madison, Available in PDF format at http://www.uwex.edu/ces/pdande/resources /index.

[EU, 2005] EU (2005). Connecting Europe at High Speed: National Broadband Strategies. Technical report, Commission of the European Communities, eEurope 2005.

[Ferguson, 2002] Ferguson, C.H. (2002). The U.S. Broadband Problem. The Brookings Institution.

[Festinger et al., 1948] Festinger, L., Stanley, S., and Back, K. (1948). Social pressures in informal groups. MIT Press.

[Fijnvandraat and Bouwman, 2006] Fijnvandraat, M. and Bouwman, H. (2006). Flexibility and broadband evolution. Telecommunications Policy, 30:424-444.

[Firth and Mellor, 2005] Firth, L. and Mellor, D. (2005). Broadband: benefits and problems. Telecommunications Policy, 29(2-3):223-236.

[Fischbacher et al., 2003] Fischbacher, U., Fong, C., and Fehr, E. (2003). Fairness, errors and the power of competition. IEW - Working Papers iewwp133, Institute for Empirical Research in Economics - IEW.

[Ford and Koutsky, 2005] Ford, G. and Koutsky, T. (2005). Broadband and Economic Development: A Municipal Case Study from Florida. Applied Economic Studies, 17(3):216-229.

[Fornefeld et al., 2008] Fornefeld, M., Delaunay, G., and Elixmann, D. (2008). The Impact of Broadband on Growth and Productivity. Technical report, MICUS Management Consulting GmbH.

[Friedman, 1962] Friedman, M. (1962). Capitalism and freedom. University of Chicago Press.

[Gillath, 2007] Gillath, I. (2007). Why Fiber is the Best Solution for Today's Web 2.0 World and for Developers. Technical Report September, Broadband Properties.

[Gillett et al., 2006] Gillett, S., Lehr, W., and Osorio, C., and Sirbu, M. A. (2006). Measuring Broadband's Economic Impact. Technical Report 99-07-13829, National Technical Assistance, Training, Research, and Evaluation Project.

[Granovetter, 1985] Granovetter, M. (1985). Economic Action and Social Structure: The Problem of Embeddedness. The American Journal of Sociology, 91(3):481-510.

[Granovetter, 2005] Granovetter, M. (2005). The Impact of Social Structure on Economic Outcomes. Journal of Economic Perspectives, 19(1):33-50.

[Griliches, 1958] Griliches, Z. (1958). Research Costs and Social Returns: Hybrid Corn and Related Innovations. Journal of Political Economy, 66:419.

[Hojman, 2004] Hojman, D. (2004). Interaction Structure and the Evolution of Conventions. Working paper, Harvard University.

[Hua, 2004] Hua, Z. (2004). Study of Multi-Agent Cooperation. In Proceedings of Third International Conference on Machine Learning and Cybernetics. IEEE.

[James and Hopkinson, 2005] James, P. and Hopkinson, P. (2005). Sustainable broadband? The Economic, Environmental and Social Impacts of Cornwall's actnow Project. Technical report, University of Bradford and SustainIT.

[Jorgenson and Griliches, 1967] Jorgenson, D.W. and Griliches, Z. (1967). The Explanation of Productivity Change. Review of Economic Studies, 34, 349-83.

[Kandori et al., 1993] Kandori, M., Mailath, G., and Rob, R. (1993). Learning, Mutation, and Long Run Equilibria in Games. Econometrica, 61(1):29-56.

[Karsak et al., 2003] Karsak, E., Sozer, S., and Alptekin, S. (2003). Product planning in quality function deployment using a combined analytic network process and goal programming approach. Computers and Industrial Engineering, 44(1):171-190.

[Katz and Rice, 2002] Katz, J. and Rice, R. (2002). Social consequences of internet use: access, involvement, and interaction. MIT Press.

[Kevin, 2001] Kevin J. Stiroh (2001). "Investing in Information Technology: Productivity Payoffs for U.S. Industries," Current Issues in Economics and Finance, Federal Reserve Bank of New York, 7:6, June 2001.

[Kirman and Vignes, 1991] Kirman, A. and Vignes, A. (1991). Price Dispersion: Theoretical Consideration and Empirical Evidence from the Marseille Fish Market. In Arrow, K., editor, Issues in Contemporary Economics: Proceedings 9th World Congress International Economy Association, volume 1. Macmillan.

[Koellinger, 2006] Koellinger, P. (2006). Impact of ICT on corporate performance, productivity and employment dynamics. Technical Report Industry, Special Report No. 01/2006, e-Business Watch, European Commission and DG Enterprise.

[Kosfeld, 2003] Kosfeld, M. (2003). Network Experiments. Working Paper Series 152, University of Zurich.

[Kranton and Minehart, 2001] Kranton, R. and Minehart, D. (2001). A Theory of Buyer-Seller Networks. American Economic Review, 91(3):485-508.

[Lee et al., 2003] Lee, H., O'Keefe, R., and Yun, K. (2003). The growth of broadband and electronic commerce in South Korea: contributing factors. The Information Society, 19(1):81-93.

[Lee et al., 2005] Lee, H., Oh, S., and Shim, Y. (2005). Do we need Broadband? Impacts of broadband in Korea. Info - The journal of policy, regulation and strategy for telecommunications, 7(4):47-56.

[Lieberman, 2002] Lieberman, J. (2002). Broadband: A 21st Century Technology and Productivity Strategy. Technical report, Office of Senator Joseph I. Lieberman.

[Liebowitz and Margolis, 1994] Liebowitz, S. and Margolis, S. (1994). Network Externality: An Uncommon Tragedy. Journal of Economic Perspectives, 8(2):133-50.

[Loannis and Anastasia, 2005] Loannis, P. C. and Anastasia, S. S. (2005). Broadband Access in the European Union: An Enabler for Technical progress, Business Renewal, & Social Development. International Journal for Infonomics, 1.

[Mackenzie, 2006] Mackenzie, K. (2006). Australia's broadband lags. The Australian, available at: http://australianit.news.com.au, No.16 January.

[Madureira et al., 2009] Madureira, A., Bouwman, H., and Baken, N. (2009). From Digital Information Networks To Emergent Economic Productivity: a framework to analyze causal relations. under submission.

[Malone and Crowston, 1990] Malone, T. and Crowston, K. (1990). What is coordination theory and how can it help design cooperative work systems? In CSCW '90: Proceedings of the 1990 ACM conference on Computer-supported cooperative work, pages 357-370. ACM Press.

[Marshall, 1890] Marshall, A. (1890). Principles of Economics. London: Mcmillan.

[Martin, 2006] Martin, D. (2006). "20 Top Tips to Writing Effective Surveys".

[Mazzuccato, 2000] Mazzuccato, M. (2000). Firm size, innovation and the market structure. Edward Elgar.

[Moss, 2007] Moss, S. (2007). Econometrics and Policy Analysis: A Critique and an Alternative. Technical report, Centre for Policy Modelling, Manchester Metropolitan University Business School.

[Nelson and Winter, 1985] Nelson, R. and Winter, S. (1985). Evolutionary Theory of Economic Change. Belknap Press.

[NetQuestionnaires Nederland BV, 2005] NetQuestionnaires Nederland BV (2005). Manual NetQuestionnaires 5.5, www.netq.nl.

[North, 1990] North, D. (1990). Institutions, Institutional Change and Economic Performance. Cambridge University Press.

[NTIA, 2008] NTIA (2008). Networked Nation: Broadband in America 2007, United States Department of Commerce, Washington, D.C.

[OECD, 2008] OECD (2008). OECD Broadband Portal. http://www.oecd.org/sti/ict/ broadband.

[Ofcom, 2005] Ofcom (2005). The Ofcom Internet and broadband update. Retrieved November 20, 2005, from http://www.broadbanduk.org/reports/Ofcom percent20Internet and Broadband percent200404.pdf.

[Pociask, 2005] Pociask, S. B. (2005). Broadband Use by Rural Small Businesses. TeleNomic Research, LLC Herndon, VA 20171.

[Pratt, 1964] Pratt, J. (1964). Risk aversion in the small and the large. Econometrica, 32(1-2):122-136.

[Ranger, 2005] Ranger, S. (2005). Broadband fuels online gambling boom. Technical Report April 14, 2005 9:52 in CNET, Silicon.com.

[Rogers, 1958] Rogers, E. (1958). Categorizing the adopters of agricultural practices. Rural Sociology, 23:346-354.

[Ryan and Gross, 1943] Ryan, B. and Gross, N. (1943). The Diffusion of Hybrid Seed Corn in Two Iowa Communities. Rural Sociology, 23:15-24.

[Saaty, 2001] Saaty, T. (2001). The Analytic Network Process: Decision Making with Dependence and Feedback. RWS Publications.

[San Antonio College Institutional Research and Effectiveness, 2007] San Antonio College Institutional Research & Effectiveness (2007). "General Guidelines for Creating Surveys".

[Sawyer et al., 2003] Sawyer, S., Allen, J. P., & Heejin, L. (2003). Broadband and mobile opportunities: A socio-technical perspective. Journal of Information Technology, 18 (4), 121-136.

[Saxenian, 1994] Saxenian, A. (1994). Regional Advantage: Culture and Competition in Sillicon Valley and Route 128. Harvard University Press.

[Shideler et al., 2007] Shideler, D., Badasyan, N., and Taylor, L. (2007). The economic impact of broadband deployment in Kentucky. Regional Economic Development, 3(2):88-118.

[SNG, 2003] SNG (2003). Economic impact study of the South Dundas township fibre network. Technical report, Strategic Networks Group.

[Solow, 1987] Solow, R. (1987). New York Review of Books.

[Spence, 1973] Spence, M. (1973). Job Market Signaling. The Quarterly Journal of Eco- nomics, 87(3):355-74.

[Standish et al., 2007] Standish, B., Boting, A., and Thompson, G. (2007). The Economic Impact of a Metropolitan Broadband Network for the City of Cape Town. Technical report, Strategic Economic Solutions cc.

[Stiglitz, 2000] Stiglitz, J. (2000). The Contributions Of The Economics Of Information To Twentieth Century Economics. The Quarterly Journal of Economics, 115(4):1441-1478.

[Strang and Tuma, 1993] Strang, D. and Tuma, N. (1993). Spatial and Temporal Heterogeneity in Diffusion. The American Journal of Sociology, 99(3):614-639.

[SusTel, 2003] SusTel (2003). Is Teleworking Sustainable? An Analysis of its Economic, Environmental and Social Impacts. Technical report, Sustainable Teleworking.

[TA, 2002] TA (2002). Understanding Broadband Demand: A Review of Critical Issues. Technical report, Office of Technology Policy, U.S. Department of Commerce.

[Tarcsi, 2007] Tarcsi, A. (2007). The Web 2.0 Business Model and a Web 2.0 Enterprise: Google. pages 143-146.

[Teece, 1980] Teece, D. (1980). Economies of scope and the scope of the enterprise. Journal of Economic Behavior & Organization, 1(3):223-247.

[Teece, 1986] Teece, D. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy, 15(6):285-305.

[Tesfatsion, 2005] Tesfatsion, L. (2005). Agent-Based Computational Modeling And Macroeconomics. Staff General Research Papers 12402, Iowa State University, Department of Economics.

[Thompson and Garbacz, 2008] Thompson, H. and Garbacz, C. (2008). Broadband Impacts on State GDP: Direct and Indirects Impacts. International Telecommunications Society 17th Biennial Conference, Canada.

[Tim, 2008] Tim, S. (2008). How To Conduct An Online Survey and Engage Customers In A Dialogue.

[Tirole, 1988] Tirole, J. (1988). The Theory of Industrial Organization. MIT Press.

[Uhrbach and van Tol, 2004] Uhrbach, M. and van Tol, B. (2004). Broadband Internet: Removing the Speed Limit for Canadian Firms. Technical Report 11-621-MIE2004016, Science, Innovation and Electronic Information Division, Ottawa.

[Uzzi, 1996] Uzzi, B. (1996). The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect. American Sociological Review, 61(4):481-505.

[Van Alstyne and Brynjolfsson, 1995] Van Alstyne, M. and Brynjolfsson, E. (1995). Communication Networks and the Rise of an Information Elite: Do Computers Help the Rich Get Richer? In ICIS, pages 93-96.

[Vega-Redondo, 2002] Vega-Redondo, F. (2002). Building Up Social Capital in a Changing World. Discussion paper, University of Alicante.

[Venkatraman, 2007] Venkatraman, N. (2007). Managing the big shift. Ericsson Business Review, (1):40-43.

[Watts et al., 2002] Watts, D. J., Dodds, P. S., and Newman, M. E. J. (2002). Identity and Search in Social Networks. Science, 296:1302.

[Wellman et al., 1996] Wellman, B., Salaff, J., Dimitrova, D., Garton, L., Gulia, M., and Haythornthwaite, C. (1996). Computer Networks as Social Networks: Collaborative Work, Telework, and Virtual Community. Annual Review of Sociology, (22):213-238.

[Williamson, 1975] Williamson, O. (1975). Markets and Hierarchies: Analysis and Antitrust Implications. Free Press.

[Winter, 1987] Winter, S. (1987). Knowledge and competence as strategic assets. In The Competitive Challenge: Strategies for Industrial Innovation and Renewal, pages 159-184. Ballinger, Cambridge, MA.

[Young, 1993] Young, P. (1993). The Evolution of Conventions. Econometrica, 61:57-84.

[Zilber et al., 2005] Zilber, J., Schneider, D., and Djwa, P. (2005). You Snooze, You Lose: The Economic Impacts of Broadband in the Peace River and South Similkameen Regions. Technical report, 7th Floor Media at Simon Fraser University, Canada.

Appendix A

Cover letter

Dear Sir/Madam,

Have you ever realized the current importance of digital information networks (e.g. Internet)? Have you ever thought why they have become so important? Obviously, Internet provides access to information. But how is the information actually used for work purposes?

The goal of this research is to investigate the relation between digital information networks and productivity at work. With your participation, we hope to contribute to clarify this relation which has been matter of extensive, but still inconclusive research.

This questionnaire should take you about 10 minutes to complete and its outcome is completely anonymous. Therefore, your responses will be treated confidentially. Please, take your time to complete it and return it after to one of our research members.

If you have any questions or concerns about this questionnaire, you may contact us with the emails below. We thank you in advance for your cooperation.

The research team,

Steven Ngabonziza
Network Architectures and Services (NAS) group
Delft University of Technology, Delft, the Netherlands
E-mail: s.ngabonzizarugemintwaza@tudelft.nl

Ir. Antonio Madureira
Network Architectures and Services (NAS) group
Delft University of Technology, Delft, the Netherlands
E-mail: a.j.pintosoaresmadureira@tudelft.nl

Prof. Nico Baken
Network Architectures and Services (NAS) group, Delft University of Technology
Corporate Strategy and Innovation department, Royal KPN, the Hague, the Netherlands
E-mail: n.h.g.baken@tudelft.nl and nico.baken@kpn.com

Appendix B

Survey's questions

Digital information networks are information networks supporting the digital economy: an economy that is based on electronic goods and services in any of the production, distribution and consumption stages. An example of a digital information network is Internet.

Broadband networks are advanced telecommunication systems capable of providing high-speed transmission of services. Examples of broadband networks are ADSL and UMTS. The term broadband is contrasted with narrowband. Generally speaking, narrowband describes telecommunication systems that carry voice information in a narrowband of frequencies. An example of narrowband networks are dial up phone networks.

Remark: the following questions intend to get your general perception about some aspects on the relation between digital information networks and productivity. This evaluation might or not directly reflect your personal experience.

Q1a *Digital information networks impact the entrustment with work colleagues.* For example, by enabling to share affective information using websites like Facebook.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q1b *The impact to the entrustment with work colleagues brought by digital information networks impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q1c *In comparison with narrowband, broadband impacts the entrustment with work colleagues.* For example, by enabling to share in-group day-out videos.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q1d *The impact to the entrustment with work colleagues brought by broadband impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q2a *Digital information networks impact the adoption or fulfillment of norms, conventions or rules within an organization.* For example, with regular email advertisement of good examples of loyalty to the organization.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q2b *The impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by digital information networks impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q2c *In comparison with narrowband, broadband impacts the adoption or fulfillment of norms, conventions or rules within an organization.* For example, with regular video conferences by the CEO about organizational values.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q2d *The impact on the adoption or fulfillment of norms, conventions or rules within an organization brought by broadband impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q3a *Digital information networks help the coordination with work colleagues.* For example, by enabling to schedule meetings and keeping track of the correspondence.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q3b *The help on the coordination with work colleagues brought by digital information networks impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q3c *In comparison with narrowband, broadband helps the coordination with work colleagues.* For example, by enabling to use video conferencing.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q3d *The help on the coordination with work colleagues brought by broadband impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q4a *Digital information networks help to find cooperation opportunities with other parties.* For example, finding business partners, providers of the inputs required by a company or consumers of the products or services delivered by a company.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q4b *The help on finding cooperation opportunities brought by digital information networks impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q4c *In comparison with narrowband, broadband helps to find cooperation opportunities with other parties.* For example, by using appealing content for marketing products or services to consumers.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q4d *The help on finding cooperation opportunities brought by broadband impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q5a *Digital information networks help the selection of information.* For example, fastening the selection using search engines such as Google.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q5b *The help on the selection of information brought by digital information networks impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q5c *In comparison with narrowband, broadband helps the selection of information.* For example, providing the outcome of the selection process using rich content.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q5d *The help on the selection of information brought by broadband impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q6a *Digital information networks help to negotiate prices for products or services.* For example, in stock trading sites or second hand online markets such as eBay.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q6b *The help on the negotiation of prices brought by digital information networks impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q6c *In comparison with narrowband, broadband helps the negotiation of prices for products or services.* For example, providing accurate and real time information about stock markets.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q6d *The help on the negotiation of prices brought by broadband impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q7a *Digital information networks help to acquire novel knowledge.* For example, by having online trainings or accessing digital libraries.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q7b *The help on acquiring novel knowledge brought by digital information networks impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q7c *In comparison with narrowband, broadband helps to acquire novel knowledge.* For example, by enabling you to download large digital documents.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q7d *The help on acquiring novel knowledge brought by broadband impacts productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q8a *Digital information networks help to become more creative.* For example, by facilitating the access to information from other areas which inspire creative work.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q8b *The help on becoming more creative brought by digital information networks impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q8c *In comparison with narrowband, broadband helps to become more creative.* For example, by enabling to express your creative creations using richer forms of content.

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q8d *The help on becoming more creative brought by broadband impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely	Mostly	Occasionally	Slightly	Not at all	Can not answer
☐	☐	☐	☐	☐	☐

Why? (optional) _____

Q9a *In comparison with traditional forms of information transfer (e.g. newspapers and letters), digital information networks change the way information is experienced.* For example, by providing a more pleasant experience using animated and interactive content, instead of a static sheet of paper.

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q9b *The change brought by digital information networks to the way information is experienced impacts productivity.*

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q9c *In comparison with narrowband, broadband changes the way information is experienced.* For example, by providing animated instead of text-based content.

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q9d *The change brought by broadband to the way information is experienced impacts productivity.*

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q10a An organization usually has a formal hierarchy (CEO, anagers, technicians,etc). But often, in practice, hierarchies are ineffective due to lack of communication between members of the hierarchy.

Digital information networks change the effectiveness of hierarchies by facilitating the communication between its members.

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q10b *The impact on the hierarchical structure of an organization brought by digital information networks impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q10c *In comparison with narrowband, broadband changes the effectiveness of hierarchies by facilatating the communication between its members.*

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q10d *The impact on the hierarchical structure of an organization brought by broadband impacts, at a longer term, productivity.*

Do you agree with this statement?

Completely ☐ Mostly ☐ Occasionally ☐ Slightly ☐ Not at all ☐ Can not answer ☐

Why? (optional) _____

Q11 In the previous questions, we requested your evaluation about the impact of digital information networks and broadband, in particular, on the following aspects:

1. Information is experienced
2. Entrustment with colleagues
3. Effective hierarchical operation of an organization
4. Adoption or fulfillment of norms, conventions or rules
5. Coordination with colleagues
6. Cooperation with colleagues
7. Selection of information
8. Negotiation of prices for products or services
9. Adoption of novel knowledge
10. Creativity at work

If you can remember any other aspect impacted by digital information networks that might have an effect upon your productivity, please specify it below.

Q12 In which of the following economic sectors are you active?

☐ Agriculture
☐ Amusement and recreation
☐ Construction
☐ Education
☐ Energy
☐ Environmental care
☐ Finance
☐ Government
☐ Healthcare
☐ Industry
☐ Media
☐ Mining
☐ Real estate Security
☐ Telecommunication
☐ Tourism
☐ Trade
☐ Transport
☐ Water
☐ Other (please specify)_____

If you have any comment to make about the questionnaire, please mention it below.

The end! Thank you again for your collaboration