Essays in Competition and Innovation - An Empirical and Theoretical Analysis

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1 Introduction[1]

The topics of *competition and innovation* are of large importance for the efficiency and prosperity of the overall economy, which is widely acknowledged in the literature (e.g., for a survey, Gilbert 2006) to be linked first, as pointed out, for instance, by Gilbert (2006, pp. 159-160), in the work of Schumpeter (1942/1947), describing competition as a “process of Creative Destruction”(Schumpeter 1942/1947, p. 83).[2,3] A dynamic understanding of competition implies according to other authors that competition is not a constant phenomenon with fixed, but changing market structures (e.g., Evans and Schmalensee 2001, pp. 11-14, pp. 15-17).[4] This indicates that both, *competition and innovation*, are mutually dependent.

The relationship between *competition and innovation*, even though not considering this mutual dependency, is not straightforward and many different effects have been discussed. For instance, Gilbert (2006) provides a detailed survey, discussing in depth the different strands of literature regarding their relationship between *competition and innovation*, of which certainly the study of Aghion et al. (2005), whose findings introduce a non-linear, “inverted-U relationship between competition and innovation”(Aghion et al. 2005, p. 703) that allows for both negative and positive impacts of competition on innovation, is the most prominent (see, Gilbert 2006, pp. 198-199, 207 referring to the above authors, describing their findings regarding the impact of competition on innovation).[5] Many open questions remain such that there still remains a lot of room for research. All these works, however, show that competition is always, even if not explicitly linked, associated with innovation.

[1]The first two paragraphs base on joint work with Margit Vanberg that has been published in an earlier ZEW documentation that only differs slightly (Vanberg and Klein 2008, pp. 6-7; Section 3.1).

[2]See, in particular, Schumpeter (1942/1947, pp. 81-86) referring to “Capitalism”(Schumpeter 1942/1947, p. 82) as dynamic systems and implicitly describing a dynamic competitive process (Schumpeter 1942/1947, p. 82-83). See also Gilbert (2006, pp. 159-160) referring to Schumpeter (1942/1947), however focusing on his findings regarding market structure and the likelihood of innovation. Consider that I refer, in the whole thesis to the revised 2nd edition of Schumpeter (1942/1947) in 1947 using its page information, which is to a large degree only a reprint, however the relevant argument goes back to 1942.

[3]See Vanberg and Klein (2008, pp. 6-7; Section 3.1); consider that this paragraph is based, as stated above on joint work with Margit Vanberg, published only slightly different in Vanberg and Klein (2008, pp. 6-7; Section 3.1).

[4]See Vanberg and Klein (2008, pp. 6-7; Section 3.1); consider, that this paragraph and this sentence is based on own joint work with Margit Vanberg and published only slightly different in (Vanberg and Klein 2008, pp. 6-7; Section 3.1).

[5]See Vanberg and Klein (2008, pp. 6-7; Section 3.1); consider that this paragraph and this sentence is based on own joint work with Margit Vanberg and published only slightly different in (Vanberg and Klein 2008, pp. 6-7; Section 3.1).

The following four chapters deal with at least one particular aspect of the topics *competition and innovation*.[6] The focus is broad, ranging from analyzing the efficiency of antitrust policies to investigating the effect of the adoption of broadband Internet on firm success measured in terms of productivity and innovation. In addition, the methods used differ as well. I apply empirical methods as well as theoretical methods to investigate a particular topic. The following chapters provide four independent essays:

Chapter 2, *Cartel Destabilization and Leniency Programs - Empirical Evidence*[7], deals with leniency programs and therefore relates to the aspect of competition, in particular antitrust policy. It is the objective of this chapter to investigate, whether the leniency programs that have been implemented by most OECD countries helped to efficiently destroy and deter cartelization and collusion. To achieve this, an international panel data is built investigating whether the implemented leniency programs exhibited a significant impact on the level of competition intensity measured on an industry level. The results can verify an impact and lead to the conclusion that national leniency programs have the desired effect in detecting and deterring cartels.

Chapter 3, *Endogenous Firm Heterogeneity, ICT and R&D Incentives*[8], relates to both topics of the thesis: *competition and innovation*. In particular, this chapter analyzes empirically how ICT has an impact on heterogeneity within industries, which in turn characterizes competition in a market. In a second step, it is analyzed how this impact translates into a change of firm incentives to invest in R&D. The chapter can verify this impact of ICT on heterogeneity, however it depends on the specific use of ICT within the firm. Moreover, it also shows evidence for a positive impact of this heterogeneity on firms' incentives to invest in R&D.

Chapter 4, *How Market Regulation Affects Network and Service Quality in Related Markets* [9], uses a theoretical model to analyze the interrelation of two complementary markets of which at least one is monopolized and price regulated (e.g., Internet broadband and Internet services). In particular, this chapter focuses on investment incentives and links

[6]The essays of chapter 3, 4 and 5 are based on joint work with co-authors. The chapters are partially published in discussion paper versions and also in project reports and were presented in different versions at numerous conferences and seminars. Moreover, they also have been refereed by anonymous referees. Detailed information on all this is given in the chapters.

[7]This chapter is based on and published in an earlier discussion paper version that only differs slightly (Klein 2010).

[8]This chapter is based on joint work with Daniel Cerquera, Centre for European Economic Research (ZEW), Mannheim. This chapter is based on and published in an earlier discussion paper version that differs slightly (Cerquera and Klein 2008).

[9]This chapter is based on joint work with Justus Haucap, Heinrich-Heine-University of Düsseldorf, Düsseldorf Institute for Competition Economics (DICE).

explicitly the price regulation of the monopolized market and the change of investment incentives in both, the regulated and the unregulated market. Though not explicitly considered, the utility derived by the investment may also be interpreted as the expected outcome of an innovation (see, e.g., using a similar kind of investments to characterize R&D Farrell and Katz 2000, p. 416). The results show in line with common knowledge that regulation decreases incentives to invest of the regulated firm, but show different effects for the unregulated firm, which are dependent on specific constellations. The impact can be either positive or negative and it is also possible that the effect is positive enough to increase overall quality.

Chapter 5, *An Empirical Analysis of Broadband Internet Use and Firm Success*[10], links empirically the firms' adoption decision on whether to adopt broadband Internet to their success, measured either in an increase in labor productivity or success in innovation. At the particular timing of the data, the provision of Internet broadband was provided at a non competitive, regulated market which can be explained as the described in chapter 4. Therefore, we show how this regulated market affects the success of firms in non-regulated markets. The strength of this chapter is the application of an instrumental variable approach using the availability of broadband Internet via DSL as an instrument. This allows causal interpretations. The study reveals two results. Firm performance measured in firms' labor productivity is not causally affected, while the firms' output in innovations is strongly and causally positively affected.

[10]This chapter is based on joint work with Irene Bertschek and Daniel Cerquera, both from the Centre for European Economic Research (ZEW), Mannheim. It is based on the project "The role of broadband Internet for corporate success" commissioned by the Deutsche Telekom AG. The chapter is based on and published in an only slightly differing project report (Bertschek et al. 2010), on and in an only slightly different discussion paper version (Bertschek et al. 2011) as well as in an unpublished feasibility study that also has major elements in common.

2 Cartel Destabilization and Leniency Programs - Empirical Evidence[1]

2.1 Introduction

A threat to free competition is the cartelization of firms. One major instrument antitrust authorities have against cartels and use increasingly frequently are leniency programs (Spagnolo 2008, p. 259, Brenner 2009, p. 639). Leniency programs, as a device for cartel detection and cartel destabilization, have been implemented, or reformed, across countries since the early nineties (e.g., OECD 2002, pp. 7-8, p. 12, OECD 2003, pp. 19-23, Spagnolo 2008, p. 259, pp. 266-268). As widely discussed in the literature, these programs allow for cartel fine avoidance or at least for significant reductions of fines for a cartel member who reports a cartel (Spagnolo 2008, p. 259). Theoretical literature widely analyzed leniency programs, showing that they can be an effective tool to destabilize, detect and deter cartels (Motta and Polo 2003, Spagnolo 2004, Chen and Harrington 2007).[2] However, negative effects are possible as well, for instance, an increase in the number of cartels may occur,"by reducing the expected fines"(Motta and Polo 2003, p. 375)[3], which is a threat to the efficiency of leniency programs (Motta and Polo 2003, Chen and Harrington 2007, Harrington 2008).[4] Empirical literature tries to analyze whether leniency programs are effective but stays inconclusive as identification is only derived from detected cartels (Brenner 2009, p. 640, Miller 2009, p. 752).[5]

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[1] Versions of this work have been presented at different conferences: 1st Düsseldorf, Leuven & Mannheim Seminar on Competition and Innovation, Düsseldorf, Germany, an internal ZEW Doctoral Seminar, Mannheim, Germany, the ZEW-Conference on Quantitative Analysis in Competition Assessment, 2010, Mannheim, Germany, the Conference of the European Economic Association (EEA), Oslo 2011, the European Association of Research in Industrial Economics (EARIE), Stockholm 2011. I'd like to thank all participants of conferences, anonymous referees as well as Irene Bertschek, Daniel Cerquera, Ralf Dewenter, Tomaso Duso, Christina Gathmann, Mark McCabe, Evgenia Motchenkova, for her detailed discussant presentation, Martin Peitz & Christine Westermann for comments and suggestions. This chapter is based on and published in an earlier discussion paper version that only differs slightly (Klein 2010). All remaining errors are mine.

[2] See also Miller (2009, pp. 750-751) discussing those studies as well as the survey of Spagnolo (2008, pp. 272-275; 276-277) referring also to these studies showing how they can be efficiently set up. However, the later cites an earlier version of Chen and Harrington (2007).

[3] See also analogous Harrington (2008, p. 217).

[4] See also discussing those studies Miller (2009, pp. 750-751) as well as the survey of Spagnolo (2008, pp. 275-277) referring to and discussing also these studies showing that negative effects of leniency are possible as well, however he refers to earlier studies of Harrington (2008), Chen and Harrington (2007).

[5] See also Spagnolo (2008, pp. 287-288), who summarizing this literature, referring to an earlier version of the Brenner 2009 paper, however, he also refers to several experiments providing interesting results regarding deterrence of cartels Spagnolo (2008, p. 285-287).

This chapter attempts to go a step further in the identification of effectiveness of leniency programs. First, I argue that the efficiency of leniency programs can be derived empirically by analyzing its direct impact on competition intensity. Competition intensity is an appropriate measure of success of the effectiveness of leniency programs, because the goal of leniency programs, as described by Spagnolo (2008, p. 264) for antitrust in general, is the prevention of cartels that are supposed to lower competition intensity (Spagnolo 2008, p. 264). Secondly, I apply a widely used measure for competition intensity (e.g., Griffith et al. 2007, Aghion et al. 2009, Buccirossi et al. 2009, Griffith et al. 2010) and show empirically that leniency programs in place lead to increased competition intensity and are, therefore, an effective tool for destroying or avoiding cartels. In executing these two steps, this chapter adds empirical evidence to the literature regarding the effectiveness of leniency programs.

The analysis relies on the theoretical literature and identifies the main objective of leniency programs, to increase, or at least to sustain, the level of competition (e.g., Spagnolo 2008, pp. 264-265). To check the hypothesis of leniency programs' effectiveness, the empirical analysis uses the OECD Structural Analysis Database (STAN, OECD 2010e), which provides information on industry level characteristics for which we use the years between 1988 until 2008, to analyze the impact of leniency on the level of competition. This data allows to build a measure of the "average profitability"(Griffith et al. 2010, p. 389) of industries, which, is given some assumptions, "equivalent to the price–cost margin"(Griffith et al. 2010, p. 399) at the industry level (Griffith et al. 2010, p. 399). The analysis, therefore, relates to the literature that analyzes effectiveness of policies that should increase competition by using the same measure as, however, an endogenous variable (Griffith et al. 2007, Griffith et al. 2010) or as a control variable (Buccirossi et al. 2009, Aghion et al. 2009). In conjunction with supplementary data of antitrust agencies and various other OECD statistics, an unbalanced panel comprising 23 countries over a period of 20 years is built. Besides the information that is necessary to construct the PCM measure, it includes a great deal of other relevant information, which allows to control for competition intensity. Supplementary information is added from other OECD databases. In addition, data to control for policies that may have an effect on the competition intensity is used as well.

Identification follows an approach similarly proposed by Buccirossi et al. (2009) in order to take account of the two main and typical sources of bias they also face, the correct direction of causality and the impact of various potentially unobserved sources on the competition intensity (Buccirossi et al. 2009, p. 8). First, analogous to them, I control for several side factors, which have an impact on competition intensity such as industry specific regulations and particular policies that should increase the level of competition (Buccirossi et al. 2009, pp. 9, 15-16). Secondly, following them an instrumental variable approach using different sets of instruments is used (Buccirossi et al. 2009, pp. 8, 9). In particular, I use the implementation of leniency programs on the OECD level (see, analogous to Buccirossi et al. 2009, pp. 9-10)[6] as well as indicators for the political environment, which are proposed by Buccirossi et al. (2009, pp. 9, 18), provided by the Manifesto database (Klingemann et al. 2006) and its update (Volkens et al. 2009).[7] Thirdly, to check for robustness, I provide several tests controlling for the impact of the European supranational leniency programs, temporal persistence of leniency programs and analogous to Buccirossi et al. (2009, pp. 5, 17, 23) for the specific legal system in which leniency programs are used.

The results indicate a positive impact of leniency programs on competition intensity, with an approximate decrease of the PCM of 3% to 4%. Moreover, the instrumental variable estimation reveals that these results do not suffer from significant endogeneity bias. Thus, national leniency programs can be considered to work efficiently in detecting and deterring cartels. This result is in line with previous findings, deriving identification from discovered cartels only. In addition, I can show that leniency programs are dependent on the legal environment where they are implemented. As a side finding, estimations show interesting correlations of the European supranational leniency programs. Finally, the overall analysis shows that efficiency of antitrust programs in general may potentially be appropriately estimated using competition intensity as a success measure.

The outline of the chapter is, as it is common, the following: Section 2 provides a background discussion and derives the hypothesis. Section 3 presents the empirical strategy, section 4 discusses the data and provides descriptive statistics. Section 5 provides empirical results, and section 6 concludes.

2.2 Literature Review and Background Discussion

The literature widely summarized the historical background on leniency programs starting 1978 with an, however, not intensively used program in the US (e.g., Spagnolo 2008, p. 266, Motta and Polo 2003, pp. 347-348, Harrington 2008, p. 215, OECD 2000, p. 12,

[6]See Buccirossi et al. (2009, pp. 9-10), proposing “using different aggregations of the potentially endogenous variables in other markets as an instrument”(Buccirossi et al. 2009, pp. 9-10). See also Friederiszick et al. (2008, p. 19) proposing this kind of instruments

[7]See Buccirossi et al. (2009, pp. 9-10). See also Friederiszick et al. (2008, p. 19) for this kind of instruments.

OECD 2003, p. 20)[8], which was, as also widely discussed, replaced by a new one in 1993, which led to far more usage (OECD 2003, p. 12, OECD 2003, pp. 19-23, Spagnolo 2008, p. 266).[9] According to Spagnolo (2008, p. 259), the revision's large success in the detection of cartels had a severe international impact such that there was an international spread of leniency programs (Spagnolo 2008, p. 259).[10] Of special importance for this study is the European leniency program, 1996, and its revision in 2002 (OECD 2003, pp. 21-22, Spagnolo 2008, pp. 267-268).[11]

Analyzing the effectiveness of those programs requires according Spagnolo (2008, p. 264) to define the "objectives of antitrust laws"(Spagnolo 2008, p. 264). Spagnolo (2008, p. 264) relates his survey on leniency programs and the objective of them to the objectives of antitrust laws in general and essentially claims "that the main objective of antitrust enforcement against cartels is avoiding that the outlawed courses of action - in our case collusive market agreements- take pace"(Spagnolo 2008, p. 264). According to him, this primary objective can be separated into two parts (Spagnolo 2008, p. 264): "*ex ante* or *general deterrence*"and "*ex post deterrence* or *desistance*"(Spagnolo 2008, p. 264). In other words the objectives of Spagnolo (2008) can be summarized as the destruction of cartels either before they occur or prosecution due to the detection of already existing cartels (see, also for the full argument, Spagnolo 2008, pp. 264-265).

Theoretical literature provides evidence that leniency programs can be an effective tool to deter cartels and, therefore, can be effective in achieving the primary objective, however also ambiguous effects are possible (see, for a survey, Spagnolo 2008). In his survey Spagnolo (2008, pp. 272-277) summarizes the literature claiming that several studies define conditions and show that given a careful setup of leniency programs there is effective deterrence of cartels (Spagnolo 2008, pp. 272-275). However, if the condition of a careful setup is not fulfilled there are several studies that he refers to showing also negative effects on collusion as well (Spagnolo 2008, pp. 275-277). Prominent examples, also referred to by Spagnolo (2008, pp. 272-275), or also by Miller (2009, pp. 750-751), are for instance, the work of Motta and Polo (2003) or Harrington (2008) who show in static environments

[8]For an excellent survey of of the literature on leniency programs see Spagnolo (2008).

[9]See also similarly Motta and Polo (2003, pp. 347-348), Harrington (2008, p. 15). See Spagnolo (2008, p. 259) also referring to OECD (2002) and OECD (2003).

[10]See also OECD (2003, p. 23) claiming that besides the US also the EU program had this influence on other countries.

[11]See also OECD (2002, pp. 7, 8), however, they do not discuss the reform in detail, however, mention its substantial changes and add the commission notice OECD (2002, pp. 67-69).

that leniency implementation can have positive as well as negative effects, which is what Harrington and Chang (2009) can also verify in a dynamic setup.[12]

These ambiguous pro-collusive effects and anti-collusive deterrence effects are explained and considered in a theoretical analysis by Harrington (2008) by three main channels. First, the "Deviator Amnesty Effect"(Harrington 2008, p. 217) changes the "payoff to cheating"(Harrington 2008, p. 217) in a cartel. Secondly, the "Cartel Amnesty Effect"(Harrington 2008, p. 217), however, "reduces the size of penalties"(Harrington 2008, p. 217). The third effect is the "Race to the Courthouse Effect"(Harrington 2008, p. 217). This effect "lowering the expected payoff from colluding"(Harrington 2008, p. 217) if less strict programs, which offer some leniency to more than the first confessor, are in place (Harrington 2008, p. 217). Therefore, the above effects work in different directions with the first lowering cartel occurrence and the second possibly increasing cartel occurrence for not optimally set up leniency programs (Harrington 2008, p. 217). The "Race to the Courthouse Effect"(Harrington 2008, p. 217), however, is claimed to be a "countervailing force for the Cartel Amnesty Effect"(Harrington 2008, p. 217). Finally, Harrington (2008, pp. 237-238) summarizes the findings of the theoretical literature showing possible positive deterrence and desistance effects on cartels, however Harrington (2008, pp. 237-238) claims that empirical evidence is missing, in particular due to data restrictions only on "*discovered* cartels"(Harrington 2008, p. 238).

There are empirical studies considering whether there has been an increase in cartel detection and deterrence due to leniency programs. Brenner (2009) uses a sample "of 61 cartel cases investigated and prosecuted by the European Commission between 1990 and 2003"(Brenner 2009, p. 640). His approach considers the impact of leniency on indicators of success right right after the leniency implementation as well as those having a durable effect (Brenner 2009, p. 644), however he cannot verify any persistent success of the leniency program (Brenner 2009, p. 644). Miller (2009) finds different evidence for the US. His empirical results indicate a peak of cartel detection after the start of the leniency program (Miller 2009, pp. 751-752). However, the decrease after this peak is stronger than the previous increase (Miller 2009, pp. 751-752). This is interpreted, with the help of a theoretical model, with a success in the objective of the leniency program to be a tool against cartels (Miller 2009, p. 765). However, his predictions rely, as he states, on a "single time series"(Miller 2009, p. 752) and on the assumption that "cartels are representative"(Miller 2009, p. 752). The study by Miller is a large step in providing

[12]See Spagnolo (2008, pp. 271-277) referring to these studies, excluding Harrington and Chang (2009), However, he refers to earlier versions of the studies by Chen and Harrington (2007) and Harrington (2008). Also Miller (2009) refers to an earlier version of Harrington and Chang (2009). In addition, the studies are the most widely referred to, see for instance the literature review in Brenner (2009).

substantial evidence that leniency programs lead to more deterrence and less collusion. However, a final conclusion is still missing, since the problems he mentions, particularly the above assumption necessary to make statements only with detected cartels, are problematic (Miller 2009, p. 752).

Given the above discussed possible negative and positive effects on the actual number of cartels (e.g., Motta and Polo 2003, Harrington 2008) and studies only taking into account detected cartels (Brenner 2009, Miller 2009), I try to use a different strategy against the data problem of undetected cartels (See, for unobservability of cartels, Harrington and Chang 2009, p. 1401). I propose to solve this measurement problem by implementing a different, more direct measure of success. In particular, taking into account the above discussion of the objectives of leniency programs (see, in particular, Spagnolo 2008, pp. 264-265), an effective leniency program leads to a situation with less cartels after the implementation of such a program (Spagnolo 2008, p. 265). If we expect that cartels, as it is common knowledge, lead to a less competitive outcome (e.g., Spagnolo 2008, p. 260), the counter factual hypothesis for a test of effectiveness of leniency programs should be whether there is a more competitive environment after the implementation of a leniency program (similarly, Spagnolo 2008, pp. 264-265). Therefore, I claim taking into account the arguments of the literature that effectiveness of leniency programs can be analyzed by investigating the intensity of competition in possibly cartelized industries. If, ceteris paribus, competition intensity increases due to the implementation of leniency programs, a leniency program is effective. Therefore, this study also relates to the literature measuring success of some kinds of competition affecting policies on different other measures of success. For instance Griffith et al. (2010) investigates, first, the impact of the European single market program on competition intensity and, then, the impact of competition intensity on innovation. Similarly, Buccirossi et al. (2009) analyzes the impact of competition policy in general on productivity.

2.3 Empirical Strategy

The objective of this study is to analyze whether leniency programs can deter and destroy cartels to improve the competitive situation in industries across OECD countries, using similar data as other studies on an industry level on related questions (e.g. Griffith et al. 2007, Buccirossi et al. 2009, Griffith et al. 2010). To achieve the objective it uses an approach similarly proposed by Buccirossi et al. (2009) such that I present, as they do, first the econometric setup (Buccirossi et al. 2009, p. 7), showing how the model in general is estimated and then present the identification strategy (Buccirossi et al. 2009, p. 8).

2.3.1 Econometric Setup

To estimate the impact of leniency programs on a measure of competition intensity, also used by Griffith et al. (2010, p. 393), we use an empirical model, which has been similarly proposed by Buccirossi et al. (2009, p. 8), however for another outcome variable. In particular, they (Buccirossi et al. 2009) try to investigate the impact of antitrust policies on productivity in a similar dataset, while we use a measure of competition intensity that Griffith et al. (2010) propose as an endogenous variable. Although their main explanatory variable, is different, it measures similarly state interference regarding competition intensity and has similar control variables that also Buccirossi et al. (2009, p. 8) uses.

Therefore, although my estimation equation is similar to the first stage model provided by Griffith et al. (2010, p. 393), which has the same outcome variable as we have, the structure of the explanatory variables including its “fixed effects”(Buccirossi et al. 2009, p. 9) is analogous to Buccirossi et al. (2009, p. 8)[13]:

$$ln(Y_{i,t}) = \beta_L Leniency_{i,t-2} + \beta_P Policies_{i,t-2} + \beta_X ln(X_{i,t-1}) + year_i + ci_t + u_{i,t} \quad (2.1)$$

with Y as a measure of the industries' competition intensity (see, similarly, Griffith et al. 2010, p. 393), *Leniency* as an indicator whether a leniency program is in place, *Policies* as a sample of other competition affecting policies, X, comprising other continuous control variables (see, similarly Buccirossi et al. 2009, p.8).[14] In addition, $year_i$ captures time dummies (Griffith et al. 2007, p. C147 Griffith et al. 2010, p. 401, Buccirossi et al. 2009, p. 8), ci_t takes account of country-industry specific fixed effects (Buccirossi et al. 2009, p. 8) and $u_{i,t}$ is, as always, the remaining error. The index t indicates timing with all dependent variables lagged by one period and all policy variables by two, because it is not clear when during a year a policy is implemented. To analyze the particular impact several issues that are discussed in the subsequent sections have to be considered.

[13]See that Buccirossi et al. (2009, p. 7) claims that his model relates to common models, for instance by Nicoletti and Scarpetta (2003), to which also Griffith et al. (2010, p. 393) refer to. However, they claim that the different analysis estimating the impact of the policies on the competition intensity measure a distinguishing element (Griffith et al. 2010, p. 393).

[14]See Buccirossi et al. (2009, p. 8), who also introduces controls in this vector. However, this is the typical notation found across many studies. To reduce the impact of potential outliers, all continuous variables, PCM and controls in X are used as logs to give more weight to smaller values.

2.3.2 Identification Strategy

Identification of the efficiency of implemented leniency programs is analyzed more directly than previous studies (Brenner 2009, Miller 2009) did, by estimating the impact on competition intensity. They measured, as discussed in the previous section, the success of leniency programs indirectly using data on detected cartels only (Brenner 2009, Miller 2009). A positive effect on competition due to leniency programs is denoted to be an indicator for more destroyed cartels (either detected or deterred). This is due to the argumentation already provided in the background discussion. First, one has to consider that successful leniency programs should ultimately deter competition-harming behavior (see, as discussed above for antitrust in general, Spagnolo 2008, pp. 264-265). As pointed out before, cartels, by definition, try to cooperate in order to increase the profits of cartel members (Spagnolo 2008, p. 260). If, ceteris paribus, cartels are deterred, a non-cooperative market outcome that is subject to more competition will arise. Therefore, instead of identifying deterred cartels (ex-ante or ex-post), the analysis relies on the effect on the final goal of leniency programs, the increase of competition intensity (see, the previously discussed argumentation on the objectives of antitrust by Spagnolo 2008, pp. 264-265).

To tackle the potential identification problems in the estimation, I follow the identification strategy of Buccirossi et al. (2009), who uses a similar industry level data set and tries to uncover the impact of competition policy, however in general on a different measure of success. The specific data and variables, in particular, the control variables are similar and are discussed similarly to them after the empirical setup. I use in particular similar steps and similar controls, to tackle the two typical problems they also face: the correct direction of causality and the impact of various potentially unobserved sources on the competition intensity (Buccirossi et al. 2009, pp. 8-9). However I adopt it for the analysis of leniency programs, which are captured in the vector $Leniency_{i,t-2}$.[15,16] Accordingly, as they claim identically in their model, the difference of the timing of the explanatory variable ensures that the direction of the effect, in my case from leniency to competition intensity, is identified correctly (Buccirossi et al. 2009, p. 9). Also identical to their strategy, relevant policies, $Policies_{i,t-2}$ (Buccirossi et al. 2009, pp. 9, 16-18) and controls, $X_{i,t-1}$ (Buccirossi et al. 2009, pp. 9, 16-18) as well as, estimation with "fixed effects" (Buccirossi et al. 2009,

[15] In contrast to my analysis, Buccirossi et al. (2009) analyze the impact of general antitrust policy on productivity. However, I use similar and partially the same instruments and, where appropriate, I follow their identification strategy for a similar industry level data set. The set of Policies controlled for is different, while the additional controls are also to a large degree identical or similar as described in the data description presented in the following subsection.

[16] See, however also Friederiszick et al. (2008, p. 19) using the same two kinds of instruments.

p. 9), captured in ci_i, should explain as much of competition intensity as possible (see, the identification strategy of Buccirossi et al. 2009, p. 9).

However, to control for remaining endogeneity of the main explanatory variable, *Leniency*, we follow Buccirossi et al. (2009) who proposes to use "instrumental variable estimation [...] to explicitly test whether endogeneity matters"(Buccirossi et al. 2009, p. 9). The instruments I use are analogous to Buccirossi et al. (2009) instruments and are separated into two classes. Besides Buccirossi et al. (2009) the same two classes of instruments have also used by other authors as Friederiszick et al. (2008, p. 19). First, I take advantage of their first kind of instruments used, the adoption of a policy in different countries (Buccirossi et al. 2009, pp. 9- 10; see, also, however, for a different research question, Friederiszick et al. 2008, pp. 19, using the regulation of markets that are next to each other, as instruments for regulation). Accordingly, I use the implementation of leniency programs in other OECD countries with a lag of one period as the first instrument, which is analogous to the ideas in Buccirossi et al. (2009) and Friederiszick et al. (2008).[17] Given the argument of Buccirossi et al. (2009, pp. 9-10) that the timing of different competition policies, for which they explicitly mention "leniency programs or the adoption of the EU competition law model in Eastern European countries"(Buccirossi et al. 2009, p. 9), is similar, this instrument should have explanatory power. To check for robustness, I add other instruments, also proposed by Buccirossi et al. (2009, pp. 9, 18), for which I use, as they do, the Manifesto data (Klingemann et al. 2006) with its update (Volkens et al. 2009).[18,19] In this study, I follow the approach and instruments proposed by Buccirossi et al. (2009, pp. 9, 18), however, also the study of Friederiszick et al. (2008, p. 19) proposes "**Political variables**"(Friederiszick et al. 2008, p. 19), for which they use also the Manifesto (Klingemann et al. 2006) data (Friederiszick et al. 2008, p. 26). These

[17]I am aware of the problem in my study that instrumenting a binary endogenous variable in my case *leniency* with a set of continuous instruments in a fixed effects estimation may be biased (See, for instance, Murtazashvili and Wooldridge (2008)). However, the instrumental variable approach in this setting serves only as a test for endogeneity bias. Moreover, given my most important instrument, the implementation of leniency in other OECD countries, which follows by the variable construction a "linear probability model"(Murtazashvili and Wooldridge 2008, p. 542) in the explanation of leniency introduction, this variable fulfills the requirements by Murtazashvili and Wooldridge (2008, p. 542). For the other instruments, I also assume this, however, since that the specific construction as in the other instrument is missing, those variables are only valid as a robustness check.

[18]Consider the potential problems in these variables mentioned above, such that they only are valid as a robustness check.

[19]See, Buccirossi et al. (2009, p. 9) provides more references for works that used this database of which one of the authors is for an subset an author there (Duso and Roeller 2003, Duso and Seldeslachts 2010). In Duso and Roeller (2003) those variables describe deregulation and in Duso and Seldeslachts (2010) they use this kind of variables to estimate "the degree of liberalization in the digital mobile telecommunications industry"(Duso and Seldeslachts 2010, p. 206). The paper Duso and Seldeslachts (2010) has been published after the publication of the Buccirossi et al. (2009) paper, which refers to the forthcoming paper, therefore, the referred to work is claimed to be newer than the referring work.

instruments of the data are items that give information regarding the general political environment (see, Klingemann et al. 2006, as well as the similar data description in Buccirossi et al. 2009, p. 18). In particular, I use the same two general categories of indicators as Buccirossi et al. (2009, p. 18), for general market interference (Buccirossi et al. 2009, p. 18) and the interference regarding social issues (Buccirossi et al. 2009, p. 18), however with slightly different items within the categories.[20] Both sets of instruments should have explanatory power for the application of leniency programs, given the similar argument of Buccirossi et al. (2009, p. 9) regarding economic policies in general, however, the latter ones are more certainly exogenous to competition intensity, while the first is potentially reversely affected by the intensity of competition.

In addition to the instrumenting strategy I try to control for two other sources of bias. First, it may be possible that leniency programs need time to become effective. I check for the importance of timing in the introduction of leniency programs and use in the standard specification different time-lags, n, of the leniency variable such that there is $Leniency_{i,t-n}$. This allows to analyze how the effect of leniency implementation depends on time. Moreover, I implement another test that has been proposed by Buccirossi et al. (2009, pp. 5, 17, 23) to control for the effectiveness of leniency programs depending on the legal environment in which they are applied, using as Buccirossi et al. (2009, pp. 5, 17, 23), the classification of (La Porta et al. 2008). Leniency programs are interacted similarly as in Buccirossi et al. (2009, pp. 5, 17, 23) with different legal systems captured in the legal system dummies and it is checked whether there are dependencies such that the variables and the interactions are added.[21] This part of the analysis uses a pooled OLS approach and country industry dummies instead of fixed effects, as the legal system is a time invariant factor that cannot be estimated using fixed effects.[22]

2.4 Data

The data is composed of several data sources. The main source is the OECD Structural Analysis Database (STAN) (OECD 2010e), which provides data on the 2 digit NACE in-

[20] See Buccirossi et al. (2009, p. 18) using a similar set of indicators regarding the importance of interference regarding social issues and only slightly different variable regarding general market interference, explained in more detail in the data section.

[21] Buccirossi et al. (2009, pp. 5, 17, 23) interacts also the indicators of the legal system with the categories of La Porta et al. (2008) to check for dependency of the legal system. However, his estimation is slightly different.

[22] See Buccirossi et al. (2009, p. 41) using a slightly different estimation for this. See Buccirossi et al. (2009, p. 23) discussing that legal origin does, of course, not vary over time and consequences for estimation.

dustry level and has been used also in other similar studies as Griffith et al. (2007,2010).[23] The data contains information on manufacturing industries as well as service industries.[24] It includes in particular various information that allow us to construct the dependent variable as well as controls. The data is complemented with information on leniency programs in place, provided by national antitrust authorities. Furthermore, information on interest rates, inflation and product market regulation from the OECD Reference Series (OECD 2010d) database, the OECD Key Economic Indicators database (OECD 2010a) and the OECD Product Market Regulation database (OECD 2010c), is added. Information of relevant policy programs that is publicly available is added as well.

2.4.1 Competition Intensity

The dependent variable of interest to identify the efficiency of leniency programs is competition intensity. To measure this intensity of competition within an industry, I use a measure of "average profitability"(Griffith et al. 2010, p. 389), which has been proposed and used, for instance, by Griffith et al. (2007), Griffith et al. (2010), Buccirossi et al. (2009) or Aghion et al. (2009). According to Griffith et al. (2010) this measure is "equivalent to the price-cost margin under the assumption of constant returns to scale"(Griffith et al. 2010, p. 399).[25]

I want to use this measure to identify the efficiency of leniency programs. However, robustness and shortcomings that has also been discussed by authors using this measure (Griffith et al. 2010, p. 389, Griffith et al. 2007, pp. C149-C150) have to be taken into account for the estimation. Griffith et al. (2010, p. 399) claims that the measure may suffer due to the assumptions of persistent too high and too low values (Griffith et al. 2010, p. 399). In another, earlier study by some of the authors, however, Griffith et al. (2007, pp. C149-C150) argue that due to concentration only on the within observation variation, persistent bias, that does not have short run fluctuations, as it is the case with this, can be tackled such that this bias is not such a problem in the estimation.

Another more severe issue discussed by Boone (2008a, 2008b) is that the PCM is not robust to all industry constellations.[26] He shows in both studies that "the rise in competition

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[23]All OECD statistics were downloaded from http://stats.oecd.org/Index.aspx, before 10.12.2010.

[24]Due to missing values in services industries, the analysis contains mostly information on manufacturing industries. An overview over the considered industries is provided in the appendix.

[25]See also Klette (1999) and Roeger (1995) to whom Griffith et al. (2010) refers to, making this argument. In the following I use the terms "average profitability"(Griffith et al. 2010, p. 389) and price-cost margin (PCM) synonymously.

[26]See in particular the discussion in Boone (2008a, pp. 599-601) as well as the discussion of the results in Boone (2008b, pp. 1256-1258).

reallocates output from inefficient firms with a low PCM to efficient firms with a high PCM"(Boone 2008a, p. 599) such that the relationship between the PCM and competition intensity is not unambiguously clear (Boone 2008a, p. 588, Boone 2008b, p. 1258).[27]

However, this problem can be mitigated if one takes into account the above argumentation by Griffith et al. (2007, pp. C149-C150). The interest of my analysis lies in a change in the measure in a persistent environment (Griffith et al. 2007, pp. C149-C150), due to cartels deterrence or destruction.[28] I claim that destroyed cartels imply a reduction of the "average profitability"(Griffith et al. 2010, p. 389) measure. If we assume that any "reallocation effect"(Boone 2008a, p. 588) as discussed by Boone (2008a, 2008b), requires time, the short run impact of a destroyed cartel should be stronger such that this should be, according to the argument by Griffith et al. (2007, pp. C149-C150), identifiable. The interpretation moreover, does not require a perfect competition intensity interpretation, but it is sufficient to show that the PCM is reduced significantly. This perspective also reduces the threat mentioned by Griffith et al. (2010, p. 399), because strong effects of destroyed cartels should not be biased too much by this drawback, but only reducing precision.

The PCM equivalent measure, "average profitability"(Griffith et al. 2010, p. 389), is calculated, according to Griffith et al. (2010, p. 399)[29]:

$$PCM_{i,t} = \frac{ValueAdded_{i,t}}{LaborCosts_{i,t} + CapitalCosts_{i,t}} \tag{2.2}$$

Griffith et al. (2010, 2007) use also, as I do, the STAN data (OECD 2010e) for the construction of the PCM and in particular information on value added and labor costs. I follow them for the construction of the measure and in the assumptions described in the following. According to Griffith et al. (2007, p. C163) capital cost are approximated by multiplying the gross fixed capital with a factor for "Cost of capital"(Griffith et al. 2007, p. C163). In particular, they use "Yield on USA Government composite bond (10 Years), minus inflation rate, plus assumed depreciation of 7%."(Griffith et al. 2007, p. C163).[30] There are different sources of information for construction of those variables, therefore the measure I use slightly differs depending on the sources. For the risk free costs of

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[27]See Boone (2008a, p. 588) calling this "reallocation effect"(Boone 2008a, p. 588). See also Buccirossi et al. (2009, p. 7) discussing these problems of the PCM in its relationship with competition referring to Boone (2000).

[28]See, as already mentioned, Griffith et al. (2007, pp. C149-C150) claim that persistent bias can be tackled, if the interest lies in changes of the measure.

[29]This measure has also been similarly used, for instance, by Buccirossi et al. (2009), Griffith et al. (2007).

[30]See also Buccirossi et al. (2009, p. 52) and Griffith et al. (2010, p. 389).

capital, I use as the other authors (Griffith et al. 2007, p. C149, Griffith et al. 2010, p. 399) the "US long-term interest rate"(Griffith et al. 2010, p. 399), which I take from the OECD Reference Series (OECD 2010d). The inflation is the country specific and annual, provided by the OECD Key Economic Indicators database (OECD 2010a).[31] The capital depreciation rate is not provided directly, therefore, I use, differently to Griffith et al. (2007, p. C163) the STAN data (OECD 2010e) and calculate it analogous to Ohnemus (2009, p. 14) as the "shares of capital consumption"(Ohnemus 2009, p. 14).[32]

The use of the capital measure the STAN data (OECD 2010e) provides information for the overall capital, however this is not used by the other authors using this data (Griffith et al. 2007, Griffith et al. 2010), or similarly the EU Klems (EU Klems Consortium 2009) data (see, Buccirossi et al. 2009), which Buccirossi et al. (2009, p. 52) claims to be a result of the rather poor data availability of this variable.[33] As a solution the other authors using this measure apply the perpetual inventory method (PIM; see, OECD 2001, for a detailed description of capital construction and in particular the PIM) to calculate a measure of capital using data on investment (Griffith et al. 2007, p. C163, Buccirossi et al. 2009, p. 52, Griffith et al. 2010, p. 399). This is what I do as well.[34] I take, according to Griffith et al. (2010, p. 399), account of another problem of the STAN data (OECD 2010e) that "capital deflators"(Griffith et al. 2010, p. 399) have many missing

[31]In contrast, Griffith et al. (2007, p. C163) uses the consumer price index from the OECD Main Economic Indicators (OECD 2010b).

[32]This data is only available for a small subset of countries of rather different size. To have an appropriate rate not biased by small economies, I use the largest economy available for the data of this variable, which is Germany. Only for industries not available in German data, I use the average of all industries available. Other authors use different depreciation rates. For instance Griffith et al. (2007, p. C163) uses a fixed depreciation rate that is set to a specific value.

[33]This issues of missing capital data has been explicitly highlighted by Buccirossi et al. (2009, p. 52), however for the EU Klems Database (EU Klems Consortium 2009). Other scholars (Griffith et al. 2010, Griffith et al. 2007) seem to consider this implicitly, because they also construct the capital in STAN data (OECD 2010e), not using the available capital measure.

[34]As discussed by Griffith et al. (2010, pp. 399-400) and Griffith et al. (2007, p. C149,p. C161) the use of the perpetual inventory method depends on the specific assumptions (Griffith et al. (2010, pp. 399-400), Griffith et al. (2007, p. C149,p. C161)) such that I check, as they propose all calculations for whether the calculated capital measure influences results significantly. I experimented with the capital assumption for the first period and finally used the method proposed by Hall and Mairesse (1995, pp. 270-271), in their case for a capital in R&D, which is referred to and discussed by Ohnemus (2009, p.15) as a possible application for common capital, however I proxy the growth rate by the growth of German capital formation. My results are consistent if gross fixed capital, as provided in the STAN data (OECD 2010e), is used (see, similarly, Griffith et al. (2007, p. C161) or Griffith et al. (2010, pp. 399-400)). The calculation of capital, however, leads to some unreasonable results for the PCM. To take account of these outliers, we drop the highest 5 percent, which have unreasonable high values. Similarly Griffith et al. (2007, p. C163) uses existing STAN (OECD 2010e) values as a benchmark for calculated values. The perpetual inventory method is also used similarly by Griffith et al. (2010), Griffith et al. (2007) and Buccirossi et al. (2009) to take account of limited data of gross fixed capital and the availability of capital formation.

values within the data, which I tackle using the idea also proposed by them, to "use cross-country averages"(Griffith et al. 2010, p. 399).

2.4.2 Main Explanatory Variable and Instruments

The main explanatory variable is the leniency program variable. Data is collected from information provided on the homepages of national antitrust authorities. As there have been several revisions of very heterogeneous leniency programs, for EU countries, I use the information in which year a leniency program according to the European Competition Network's definition (European Competition Network 2009, Annex 1) has been in place.[35] This ensures that heterogeneity of leniency programs observed is reduced and that it is ensured that the first confessor receives full amnesty. The variable is constructed as a dummy, indicating whether such a program exists at a given time. Moreover, two more dummy variables consider if the European supranational leniency programs affect an industry. Therefore, a dummy for the first EU leniency program in 1996 and its revision in 2002 are considered.[36] In addition, I add a variable indicating whether the countries' neighbors (if they are in the OECD) introduced leniency programs. This variable controls whether there are spillover effects.[37] The reasoning behind is that there may be cartels across borders. This is even more the case in European countries, which have strong interrelated economies, but applies also to other countries. Therefore, there may be effects of cartels detected or deterred in neighbor countries.

To control for possible endogeneity, two kinds of instruments, which are as discussed in the identification strategy analogous to the of Buccirossi et al. (2009) and Friederiszick et al. (2008, p. 19), for an instrumental variable estimation are constructed. The first instrument provided is the percentage of other OECD countries having implemented a leniency program, which takes advantage, as discussed above, of the idea of Buccirossi et al. (2009, pp. 9-10) for "different aggregations"(Buccirossi et al. 2009, p. 9) of the policy variable of interest.[38] The country for which the variable is observed is excluded inside the construction of this variable. Second, I use as Buccirossi et al. (2009, pp. 9, 18), a set of "political variables"(Buccirossi et al. 2009, p. 9) that are constructed as in

[35] See European Competition Network (2009, Annex 1). For the UK, I used the introduction of the legal basis for the leniency program rather than the last revisions.

[36] In particular, the leniency program of 1996 did not ensure full amnesty while the revision in 2002 added this important point (Spagnolo 2008, p. 290).

[37] Variables of neighboring countries are used, for instance, by Friederiszick et al. (2008, p. 19) as instruments. I, however, claim that adoption of policies is determined on the OECD level and neighbors have an effect due to spillover effects in trade.

[38] See, Friederiszick et al. (2008, p. 19) also information of policies in related regions as an instrument.

their study using the Manifesto data (Klingemann et al. 2006) with its update (Volkens et al. 2009).[39] This data provides information on the "political parties' programmatic position"(Buccirossi et al. 2009, p. 18) regarding different topics (Buccirossi et al. 2009, p. 18).[40] To construct a measure for a country, I take account of the composition of the last parliament (see, similar, Buccirossi et al. 2009, p. 18).[41] The categories relevant for this analysis are twofold and analogous to the kind of items in Buccirossi et al. (2009, p. 18). First, I use, analogous to Buccirossi et al. (2009, p. 18) indicators for the interference regarding social issues. In particular, I use the item "**Welfare state limitations planning (per505)**"(Buccirossi et al. 2009, p. 18), which is also used by them, indicating it by the Manifestos dataset name (Klingemann et al. 2006) in the following as "***Welfare State Limitation***"(Klingemann et al. 2006, p. 158), and "**Welfare**"(Klingemann et al. 2006, p. 163).[42,43] As a second type of variables for the use as an instrument, I use the item "**Planeco**"(Klingemann et al. 2006, p. 163), which indicates even more directly and similarly to the items used by Buccirossi et al. (2009, p. 18) how much interference by the state is desired (Buccirossi et al. 2009, p. 18).[44] This variable, however, may be subject to changes in a country's general competition intensity, because economic planning indicates severe interference in the general market process. Therefore, this variable is only valid as a robustness check.

[39]See, as already discussed in the empirical strategy, Friederiszick et al. (2008, p. 19) also using this kind of instruments.

[40]See also data description in Klingemann et al. (2006). Consider that I refer with Klingemann et al. (2006) both, the CD-ROm as well as the accompanying book. In particular, when referring to pages the book is meant. Buccirossi et al. (2009) uses also this data and nearly identically these variables. He discusses all the variables on page 18 of his work. To improve readability we only use italics for the original Manifesto names and discuss and state were Buccirossi et al. (2009) uses the same items without putting them into quotation marks.

[41]See Buccirossi et al. (2009, p. 18), who use only the information on the parties in the government. In contrast I assume that even though the government parties can theoretically implement their position, they will consider, at least partially, what voters consider as favorable policies, because they also seek those voters which did not vote for them before. The 2006 data is enriched with the updates available at the Manifesto's project homepage. In addition, I assumed, for missing values, that a new parliament is in place for at least two years. However, all results are robust to not imposing this assumption.

[42]See, that when I cite the variable names I omit in contrast to the data description, whether they are calibrated either as positive or negative items, as this is not an important issue here an reduces readability. For instance the variables are indicates as "***Social Justice:Positive***"(Klingemann et al. 2006, p. 158), where I omit the "***:Positive***"(Klingemann et al. 2006, p. 158) or respectively an opposite indication. These information are not added in the compound variables.

[43]See Buccirossi et al. (2009, p. 18) also uses indicators for this, in particular, also the "**Welfare state limitations planning (per505)**"(Buccirossi et al. 2009, p. 18) and argues similar. "***Welfare***"(Klingemann et al. 2006, p. 163) is a compound variable of the items "***Social Justice***"(Klingemann et al. 2006, p. 158) and "***Welfare State Expansion***"(Klingemann et al. 2006, p. 158).

[44]See Buccirossi et al. (2009, p. 18), who uses the items "**Market regulation (per403)**"(Buccirossi et al. 2009, p. 18) and "**Economic planning (per404)**"(Buccirossi et al. 2009, p. 18) of which "**Planeco**"(Klingemann et al. 2006, p. 158) is together with "***Controlled Economy***"(Klingemann et al. 2006, p. 157) a compound variable and makes a similar argument.

2.4.3 Further Control Variables

The potential controls for industry level analysis are limited, which can be seen also in the other studies using this kind of data for similar investigations (e.g. Syverson 2004, Griffith et al. 2007, Buccirossi et al. 2009, Griffith et al. 2010) such that a lot of variation is uncovered with dummies or fixed effects. Clearly, available controls are limited and, therefore, very similar across the different studies.

The measure used for competition intensity, the "average profitability"(Griffith et al. 2010, p. 389), is influenced by the general economic environment (Griffith et al. 2007, p. C149 Grittith et al. 2010, p. 401). This, however is true for most industry level variables such as, for instance, TFP (Buccirossi et al. 2009, pp. 17-18). I implement similar to Griffith et al. (2007, p. C149) a "deviation from trend output growth"(Griffith et al. 2007, p. 149) variable. To control for this source of variation, I take into account national GDP taken from the OECD Reference Series (OECD 2010d).[45] Computation is also similar to Buccirossi et al. (2009, pp. 17-18), who implements a similar variable for TFP, estimating "deviations from a linear and a quadratic trend"(Buccirossi et al. 2009, p. 17), which we also consider.

As widely described in the literature imports having explanatory power for accessibility of an industry that has an impact on competition intensity and effect the level of competition within that industry (Syverson 2004, p. 542, Aghion et al. 2009, pp. 20-21, Buccirossi et al. 2009, p. 16). First, I use absolute values of imports in an industry and, secondly, I use "import penetration"(Aghion et al. 2009, p. 21). Similarly, also Syverson (2004, p. 542), Aghion et al. (2009, pp. 20-21) Buccirossi et al. (2009, p. 16) use this, relative import intensity as the "ratio of industry import over output"(Aghion et al. 2009, p. 24), with output measured in value added (as, for instance, in Buccirossi et al. 2009, p. 16) and import data from the OECD STAN data (OECD 2010e).[46] Even though the relative import intensity is seemingly more informative, it reflects changes in both value added and imports. To capture only changes in imports, I also add the absolute value as a control variable.

To control for country specific regulatory environment on markets, I use following the idea of Buccirossi et al. (2009, p. 16), the OECD Product Market Regulation (PMR) database (OECD 2010c). This database provides us with an index regarding the intensity of regulation (Buccirossi et al. 2009, p. 16). Data is available for 1998, 2003, and 2008.

[45] All continuous variables are measured in Billion units of national currency.

[46] See also Buccirossi et al. (2009, p. 16) using the STAN data to calculate the same variable.

As there are always 5 missing years in between, I use a linear interpolation in the years between the data points, aware that this introduces measurement errors. This implies that an interpretation has to be careful, though it still remains a proper, but imprecise control variable.

In order to control for at least European changes in the product market competition I add a dummy variable, controlling for the European Single Market Program in 1992 as an important policy (See, Griffith et al. 2007, and Griffith et al. 2010, also, however, differently, controlling for this). This program abolished market entry barriers and has been shown to increase competition intensity significantly in the European Union (Griffith et al. 2010).

Relevant for the competition intensity in the EU, I control for the EU east enlargement in 2004 as two important policies. A dummy variable is created for the EU member states to take account of this structural break, which should have an effect on competition in European Markets. Moreover, I add a dummy for the new member states, because they should be affected more severe by the EU entrance than the old member states.

To control different effectiveness of leniency programs due to legal aspects, I use, as in Buccirossi et al. (2009, pp. 17, 23), controls for the legal system and construct interactions between the legal system and the leniency program variable. The classification of legal systems follows La Porta et al. (2008) and subdivides legal systems into those of English, French, German and Scandinavian origin (see, Buccirossi et al. 2009, pp. 5, 17, 23, also using the classification of La Porta et al. (2008)). The intuition behind this is that legal instruments, as the leniency program, depend systematically on the underlying legal system (Buccirossi et al. 2009, p. 23).[47] Therefore, this variable allows to capture some of the general, underlying mechanisms important for the efficiency of leniency programs.

2.5 Empirical Analysis

2.5.1 Descriptive Analysis

Table 2.1 shows which countries adopted leniency at what time. The first country adopting a leniency program was the US. After this, it took five years until the next country, the UK introduced a national leniency program in 1998 as well. However, in 1996, all

[47]See Buccirossi et al. (2009, p. 23) showing that the legal system has an important impact for the efficiency of antitrust instruments.

European Unions (EU) member states have been affected by the first supra national leniency program. Beginning with the year 2000, the adoption rate of national leniency programs increased. Importantly, the EU revised its leniency programs substantially in 2002. However, due to the EU enlargement in 2004, the EU leniency program affected some countries since then.

Table 2.2 provides information on the countries for which we have sufficient information within the data to provide estimates.[48] It can be observed that the distribution of observations is relatively similar across countries, with small countries as Luxembourg, New Zealand and Portugal as well as transformation countries as Hungary and Poland having less observations than the average. Some OECD countries are missing in the estimation due to missing data (i.e. Australia, Slovak Republic). Table 2.3 contains the industries used for estimations and shows clearly a dominance of the manufacturing industries. This dominance is due to data availability and missing values for service sectors.

Table 2.4 shows the main variables for one of the largest estimation samples. The PCM has the size of 1.31 but a rather large standard deviation. It has to be noted that data shows, as in Griffith et al. (2010, p. 401) discussed, an increasing values for the PCM over time.[49] This is in the same manner as in the Griffith et al. (2010, p. 401) paper not a significant problem as the focus in the analysis on "differentials"(Griffith et al. 2010, p. 401) mitigates this problem (Griffith et al. 2010, p. 401).[50] In 28 % of the observations,[51] a national leniency program is installed. Moreover, 53% are subject to the first EU leniency program and 29% to its revision. The OECD PMR index (OECD 2010c) has an average size of 1.82. 66% of the observations are treated by the European Single Market Program, which indicates that the data consists mostly of EU member states. This can also be seen in the percentage of observations treated by the EU enlargement in 2004, which is around 20%.

2.5.2 Econometric Analysis

Table 2.5 provides basic estimations analyzing the impact of leniency programs on competition intensity. Column (1) shows as a baseline a pooled OLS estimation, but a significant effect of leniency programs on the PCM cannot be revealed. As this may be due to

[48]For Australia and the Slovak Republic, not all necessary variables are non-missing.

[49]Griffith et al. (2010, p. 401) mentions that this is finding has been subject to other authors discussion and refers to Blanchard and Giavazzi (2003), claiming that they propose that a decreasing bargaining power of workers may be one reason for this pattern (Griffith et al. 2010, p. 401).

[50]See Griffith et al. (2010, p. 401) also using this argument.

[51]An observation is defined as values of a specific country within a specific year.

time-invariant unobservable heterogeneity, column (2) provides a fixed effects estimation. There is a significant impact of the national leniency program variable on the PCM (coeff. -0.0308, std. error 0.0149). National leniency programs have been complemented in the EU by supranational leniency programs (introduction in 1996 and major revision in 2002). Column (3) adds controls for the EU program's implementation and its major revision in 2002. Estimation shows that the impact of the first European leniency program on the PCM is negative and not significant (coeff: -0.0006, std. error: 0.0193), as well as its revision in 2002 (coeff: -0.0103, std. error: 0.0159). The impact of the national leniency program remains significantly negative (coeff: -0.0318, std: error 0.0147). Column (4) adds a control for neighbor countries' national leniency programs and identifies a positive, significant impact (coeff: 0.0427, std. error: 0.0216). This positive coefficient indicates that leniency programs seem to have an impact on the outcome even if implemented in neighboring countries. This may be explained by less market power of foreign input provider. The controls for the European supranational leniency programs is not statistical different from zero, the control for the national leniency program, however, stays strongly significant and negative. This indicates that national leniency programs are positively correlated with a higher competition intensity.

Table 2.6 adds further factors that are supposed to have an impact on industries' competition intensity in order to reduce possibly omitted variable bias. Column (1) provides the baseline estimation with the national leniency program being significant. A major policy program, which has had an impact on competition in European markets, has been the European Single Market Program in 1992, for which a control is added in column (2). The effect on the PCM is negative and strongly significant and the effect of national leniency programs stays significant (coeff: -0.0280, std. error: 0.0150). However, the effect of the European Union's program turns positive and significant for the first program. It is not clear why this happens, however, there may be other unobserved factors in 1996, which is a problem due to only limited variance in the variable. Column (3) considers the impact of the European Union's enlargement in 2004, which increased the European single market significantly. Moreover, the enlargement took place in the time when national leniency programs were implemented in the EU. Therefore, it may reduce too strong of an effect of the national leniency program. In particular, it can be seen that there is no effect on the PCM. However, controlling for these variables, the significant impact of national leniency programs remains unchanged and robust (coeff: -0.0298, std. error: 0.0155). Column (4) adds the control for the countries' particular regulation on product markets. As expected, more product market regulation leads to a higher PCM and, therefore, less competition on those markets. This effect is significant at the 5% level, without reducing the significant impact of leniency programs on the PCM. Results indicate that the effect of leniency programs is persistent and robust to different other factors (coeff: -0.0378, std. error: 0.0160), which have an impact on the competition intensity.

In order to test whether the previously observed and persistent effect of leniency programs can be interpreted causally, I introduce, as discussed above analogous to Buccirossi et al. (2009, p. 8) an instrumental variable regression in table 2.7, which allows us to explicitly test for that via a “Wu-Hausman”(Buccirossi et al. 2009, p. 22) as in Buccirossi et al. (2009, pp. 21-22).[52] In particular, as in Buccirossi et al. (2009, pp. 21-22) I introduce step by step the instruments and test whether there is endogeneity between leniency and the PCM and test via the “Sargan statistic”(Buccirossi et al. 2009, p. 22) whether the instruments are valid. However, similar to Buccirossi et al. (2009, pp. 21-22) we cannot reveal endogeneity in any specification. In particular, column (1) offers a basic regression with the previously used control variables. I use leniency program application in other OECD countries, with a one period lag to the leniency implementation, as an instrument and can verify the previously found negative impact of leniency programs on the PCM. In other words, this means the programs’ positive impact on competition intensity. The effect is close to the size of the OLS estimates (coeff: -0.0477 std. error: 0.0149). First stage regression reveals as in Buccirossi et al. (2009, p. 22) strong significance of the instrument in the first stage, backing the instrument (see, argument by Buccirossi et al. 2009, p. 22).[53] Remember that this instrument is the most important in the estimation, as it clearly is consistent. Column (2) adds the first instrument of the set of the Manifesto instruments “**Welfare**”(Klingemann et al. 2006, p. 163).[54] This second instrument allows us as in Buccirossi et al. (2009, pp. 22) to calculate “the Sargan statistic”(Buccirossi et al. 2009, p. 22) on the validity of the instruments (see, for the overidentification test, Buccirossi et al. 2009, p. 22), which yields a p-value of 62%, such that the test shows validity of the instruments. Importantly, the impact of leniency programs on the PCM remains negative (coeff: -0.0669 std. error: 0.0202) and reduces the strength of the impact to approximately the same level as the OLS estimation. Column (3) adds the

[52] See similar table as in Buccirossi et al. (2009, p. 40, Table 4)

[53] See Buccirossi et al. (2009) similar to us only presenting second stage regression for readability. Similar to him, however, the coefficient of our most important instrument is high, with significance at the 1% level. The coefficient however is negative, which is due to the effect of the time dummies capturing the trend and also an increasing trend in the implementation, which is like a time constant on which the OECD leniency is deduced. Moreover, as we have a linear probability model I checked how sensitive the results are for predictions with a probability for leniency slightly above 100% or slightly below 0% predictions. If I estimate the linear predictions for leniency and drop all observations for which a probability of above one and below zero is estimated, then the significant negative effect and the non-endogenous relation in the hausman test holds such that I am confident that if a bias exists, this should not be severe.

[54] Remember that these instruments only serve as a robustness check.

second policy program variable "***Welfare State Limitation***"(Klingemann et al. 2006, p. 158). The same impact of leniency programs on the PCM (coeff: -0.0659, std. error: 0.0201) and the tests shows still the same. Column (4) adds the "**Planeco**"(Klingemann et al. 2006, p. 163) variable to the instrumental variables, which does not change the results and seem to confirm still a non-endogenous relationship, however, the validity of instruments is rejected such that this columns estimation are not consistent. This pattern is what one should expect given the previously discussed possible reverse causality in this variable, which, however, shows that these policy instruments in general seem to work as expected. Considering these results, most important the results of column (1), the relationship between leniency program implementation and the PCM does not seem to be subject of bias feared in the estimation strategy, allowing causal interpretation of the OLS estimation, which is identically done in the analogous setup with the equivalent results also by Buccirossi et al. (2009, p. 22).[55] As a side finding, the estimations show that in the first column, the revision of the European supranational leniency program is as before positive significant, but becomes insignificant afterwards. Interestingly, the revision has a negative and significant impact, which is what one would expect. This may new results may arise, because there may be some interrelation between the national leniency and the supranational leniency which is solved by instrumenting national leniency. However, the interpretation needs to be cautious.

Table 2.8 analyzes the importance of time lags regarding the measurement of leniency programs. This is an important test to check whether the impact of leniency programs is observable only in one period or persistently over time. Estimations use the full set of variables. In columns (1) to (6), the leniency program variable is used first with no time lags and then increased up to 5 years of time lag. The impact on the PCM is negative and significant for all lags, with a similar impact, however there seems to be a slightly increasing trend in time. This trend, however, is not strictly monotonous as without a lag of one period and one of four periods the impact is slightly lower than with a lag less. However, the overall impact goes from (coeff.: -0.0293) in column (1) to (coeff.:-0.0440) in column (6). This may be interpreted cautiously that it takes time until the full benefits of leniency programs become effective.

[55] Buccirossi et al. (2009, p. 22) also making the same argument as we do here interpreting the IV estimates and the tests that the same picture regarding the tests leads to a possible causal interpretation of the OLS coefficients. The variable "**Planeco**"(Klingemann et al. 2006, p. 163) is not significant in the first stage if it is used together with the other political variables, however, it is significant without using them, indicating predictive power as an instrument. This specification is still informative as it helps to test overall validity of the instruments using the Sargan over-identification test.

The effectiveness of leniency programs depends on a variety of specific conditions. One condition which has a rather strong effect is the legal environment in which a leniency program is in place.[56] Table 2.9 analyzes the dependency of the legal system.[57] Our specification uses country industry dummies to remain as close as possible to the previously discussed fixed effects estimation. Column (1) introduces controls for the legal system as in Buccirossi et al. (2009). However, one has to take into account that standard errors are not clustered such that they may be too low. Clustering, however is not possible due to a lack of variance.[58] As the baseline, I use the French legal system. It can be seen that on average, profits are lower in countries with the English, Scandinavian and German legal system. The pooled OLS can identify a negative and significant value for the national leniency program.[59] Column (2) introduces, analogous Buccirossi et al. (2009, p. 23, p. 41), an interaction term between the legal system with leniency programs. Results show that the impact of leniency programs is still negative and significant. However, interaction effects indicate different efficiency of leniency variables within the different legal systems. The positive and significant coefficients in the Scandinavian legal systems seem to provide some, however not too strong evidence, of less efficiency of leniency programs applied there.[60] Even though it is not clear how efficient the pooled OLS estimation is, it seems to be clear that the institutional factors are important. Columns (3) and (4) add additional control variables. In column (3), the overall leniency effect remains significant, identically to column (4). The interaction remains only for the Scandinavian legal system countries positively significant. These results indicate that leniency programs are actually not only effective by themselves, but dependent on the environment where they are implemented.[61] The environment itself seems to affect strongly the competition intensity. However, results provide only a first hint, because standard errors may be underestimated due to missing clustering.

[56]See Buccirossi et al. (2009, p. 23) arguing similar for competition policy in general.

[57]See similar table in Buccirossi et al. (2009, p. 41):Table 5.

[58]Buccirossi et al. (2009) performs a different approach in a fixed effects approach.

[59]The previously used pooled OLS estimation uses different dummies and, therefore, the results differ.

[60]See Buccirossi et al. (2009, p. 22) having contrasting findings as they show competition policy in general to be more effective, however on productivity, in countries with Scandinavian and German legal system. This is not analogous for leniency programs on competition intensity.

[61]See Buccirossi et al. (2009, pp. 23-25) showing this pattern for competition policy in general.

2.6 Conclusions

This study proposed to infer efficiency of leniency programs by using the PCM as a measure of competition intensity. I argued that increasing competition intensity indicates that leniency programs destroy cartels (either due to detection or deterrence). Empirical analysis shows that leniency programs have a robust and throughout negative impact on the PCM, which is approximately between 3 % and 4 %. This implies a positive impact on the competitive environment at the industry level. The study does not directly investigate whether this impact is due to detection of cartels or due to deterrence of cartels, but as the number of detected cartels is presumably not large enough to have an impact on a too large number of industries, this study provides evidence that cartels are destabilized and deterred. This chapter takes account of various relevant issues that may bias this finding. This leads to clear support of the provided estimations and backs the found evidence for effectiveness of leniency programs in the OECD countries, indicating a causal impact of leniency programs on competition intensity. This study, therefore, complements the previous studies on this topic, tackling, however, their main drawback of incomplete identification based on detected cartels only.

Beside this main finding, the study provides some further interesting results. I was able to show that the effect of leniency on competition intensity increases slightly over time. This indicates that leniency programs need some time before becoming fully effective. As an additional result, it can be stated that the underlying legal system in which those leniency programs can be found seem to have an impact as proposed similar for other variables in the literature as well. Regressions indicate some correlations that may be interesting for further research on detailed conditions of leniency programs to work appropriately. As a side finding, correlations between the supranational EU leniency programs and competition intensity can be found, however, these correlations are not robust when controlling for other sources of variation in the competition intensity.

2.7 Appendix

Table 2.1: Leniency Implementation in OECD Countries

Country	*National Leniency Program*	*Affected by 1st EU Leniency Program (1996)*	*Affected by 2nd EU Leniency Program (2002)*
Australia	2003		
Austria	2006	x	x
Belgium	2007	x	x
Canada	2000		
Czech Republic	2001		2004
Denmark	2007	x	x
Finland	2004	x	x
France	2001	x	x
Germany	2006	x	x
Greece	2006	x	x
Hungary	2003		2004
Ireland	2001	x	x
Italy	2007	x	x
Japan	2006		
Korea	2002		
Luxembourg	2004	x	x
Netherlands	2002	x	x
New Zealand	2000		
Norway	2004		
Poland	2004		2004
Portugal	2006	x	x
Slovak Republic	2001		2004
Spain	2008	x	x
Sweden	2002	x	x
Switzerland	2003		
United Kingdom	1998	x	x
United States	1993		

The Czech Republic, Hungary, Poland and the Slovak Republic joined the EU in 2004.
Therefore, the EU leniency revision is only considered to be in place since 2004.
The definition when a leniency program is effectively in place orients
on the first reform implementing an ECN equivalent leniency program.
Source: Information from Antitrust agencies webpages, European Competition Network.

Table 2.2: Countries and Observations

Country	*Observations*	*Percent*	*Cumulative*
Austria	220	6.68	6.68
Belgium	177	5.38	12.06
Canada	122	3.71	15.77
Czech Republic	165	5.01	20.78
Denmark	178	5.41	26.18
Finland	206	6.26	32.44
France	111	3.37	35.81
Germany	190	5.77	41.59
Greece	99	3.01	44.59
Hungary	100	3.04	47.63
Ireland	102	3.10	50.73
Italy	187	5.68	56.41
Korea	74	2.25	58.66
Luxembourg	63	1.91	60.57
Netherlands	234	7.11	67.68
New Zealand	49	1.49	69.17
Norway	208	6.32	75.49
Poland	98	2.98	78.46
Portugal	79	2.40	80.86
Spain	165	5.01	85.87
Sweden	150	4.56	90.43
United Kingdom	152	4.62	95.05
United States	163	4.95	100.00
Total	3,292	100.00	

Source: OECD STAN (OECD 2010e).

Table 2.3: Industries and Observations

Industry	*Observations*	*Percent*	*Cumulative*
Fishing, fish hatcheries, fish farms and related services	211	6.41	6.41
Other mining and quarrying	57	1.73	8.14
Food products and beverages	38	1.15	9.30
Tobacco products	79	2.40	11.70
Wearing apparel	183	5.56	17.25
Leather, leather products and footwear	244	7.41	24.67
Wood and products of wood and cork	294	8.93	33.60
Printing and publishing	226	6.87	40.46
Coke, refined petroleum products and nuclear fuel	8	0.24	40.70
Chemicals and chemical products	159	4.83	45.53
Rubber and plastics products	257	7.81	53.34
Other non-metallic mineral products	341	10.36	63.70
Fabricated metal products, except machinery and equipment	142	4.31	68.01
Electrical machinery and apparatus, n.e.c.	170	5.16	73.18
Radio, television and communication equipment	236	7.17	80.35
Medical, precision and optical instruments	229	6.96	87.30
Other transport equipment	173	5.26	92.56
Electricity, gas, steam and hot water supply	27	0.82	93.38
Research and development	17	0.52	93.89
Other business activities	186	5.65	99.54
Public admin. and defence - compulsory social security	15	0.46	100.00
Total	3,292	100.00	

Source: OECD STAN (OECD 2010e).

Table 2.4: Main Variables

Variable	*Observations*	*Mean*	*Standard Deviation*
PCM	3292	1.3070	0.3122
National Leniency Program	3292	0.2764	0.4473
1st European Leniency	3292	0.5325	0.4990
2nd European Leniency	3292	0.2886	0.4532
OECD PMR Index	3079	1.8171	0.5626
Single Market Program	3292	0.6561	0.4751
Leniency Program in Neighbor Country	3109	0.3342	0.4062
EU 2004 enlargement	3292	0.2032	0.4025
New EU member in 2004	3292	0.0395	0.1948
English Legal System	3292	0.1786	0.3831
German Legal System	3292	0.2573	0.4372
Scandinavian Legal System	3292	0.2254	0.4179
French Legal System	3292	0.3387	0.4733
GDP Trend	3292	0.5373	3.3783
Imports (as a share of value added)	3292	3.64e-09	2.38e-08
Imports (absolute)	3292	129.8013	1421.778

Imports and import penetration are measured in Billions of national currency. Leniency in neighbor countries is measured since 1990. Source: OECD STAN (OECD 2010e), La Porta et al. 2008, auxiliary sources mentioned in data (OECD 2010d, OECD 2010c, OECD 2010a) description, own calculations.

Table 2.5: Leniency Programs Basic Estimations

	ln(PCM) Pooled OLS (1)	ln(PCM) Fixed Effects (2)	ln(PCM) Fixed Effects (3)	ln(PCM) Fixed Effects (4)
National Leniency (2 lags)	-0.0141	-0.0308**	-0.0318**	-0.0294*
	(0.0189)	(0.0149)	(0.0147)	(0.0152)
1st EU Leniency (2 lags)			-0.0006	0.0112
			(0.0193)	(0.0184)
2nd EU Leniency (2 lags)			-0.0103	-0.0079
			(0.0159)	(0.0154)
Leniency N. Country (2 lags)				0.0427**
				(0.0216)
GDP Trend (in logs,1 lag)	0.0089***	0.0043	0.0043	0.0029
	(0.0016)	(0.0029)	(0.0028)	(0.0030)
Import penetration (in logs, 1 lag)	-0.1385***	-0.2415***	-0.2407***	-0.2305***
	(0.0166)	(0.0544)	(0.0546)	(0.0543)
Imports (in logs, 1 lag)	0.1476***	0.2011***	0.1999***	0.1862***
	(0.0188)	(0.0508)	(0.0510)	(0.0509)
Industry dummies	x			
Country dummies	x			
Time dummies	x	x	x	x
Constant	-5.5071***	-9.1975***	-9.1576***	-8.6718***
	(0.6815)	(2.1542)	(2.1613)	(2.1627)
R^2	0.3452	0.1754	0.1756	0.1709
Observations	2736	2736	2736	2648

Robust Standard errors are in brackets.
*Significant at 1% ***, significant at 5 % ** , significant at 10% **

Table 2.6: Leniency and Competition Affecting Programs

	ln(PCM) Fixed Effects (1)	ln(PCM) Fixed Effects (2)	ln(PCM) Fixed Effects (3)	ln(PCM) Fixed Effects (4)
National Leniency (2 lags)	-0.0294*	-0.0280*	-0.0298*	-0.0378**
	(0.0152)	(0.0150)	(0.0155)	(0.0160)
1st EU Leniency (2 lags)	0.0112	0.0433**	0.0414*	0.0447**
	(0.0184)	(0.0205)	(0.0219)	(0.0219)
2nd EU Leniency (2 lags)	-0.0079	-0.0062	-0.0089	-0.0155
	(0.0154)	(0.0156)	(0.0150)	(0.0153)
Leniency N. Country (2 lags)	0.0427**	0.0395*	0.0380*	0.0301
	(0.0216)	(0.0215)	(0.0217)	(0.0226)
Single Market Program (2 lags)		-0.0617***	-0.0701***	-0.0576***
		(0.0209)	(0.0215)	(0.0202)
EU 2004 enlargement (2 lags)			0.0063	0.0151
			(0.0294)	(0.0299)
New EU member in 2004 (2 lags)			0.0220	0.0390
			(0.0426)	(0.0431)
PMR Index (2 lags, in logs				0.1154**
				(0.0511)
GDP Trend (in logs, 1 lag)	0.0029	0.0026	0.0026	0.0019
	(0.0030)	(0.0030)	(0.0030)	(0.0031)
Import penetration (in logs,	-0.2305***	-0.2306***	-0.2289***	-0.2225***
	(0.0543)	(0.0541)	(0.0547)	(0.0548)
Imports (in logs, 1 lag)	0.1862***	0.1848***	0.1823***	0.1858***
	(0.0509)	(0.0506)	(0.0514)	(0.0505)
Time dummies	x	x	x	x
Constant	-8.6718***	-8.6445***	-8.5572***	-8.7428***
	(2.1627)	(2.1527)	(2.1829)	(2.1423)
R^2	0.1709	0.1755	0.1757	0.1641
Observations	2648	2648	2648	2531

Robust Standard errors are in brackets.
*Significant at 1% ***, significant at 5 % ** , significant at 10% **

Table 2.7: Instrumental Variable Estimation

	ln(PCM) IV (1)	ln(PCM) IV (2)	ln(PCM) IV (3)	ln(PCM) IV (4)
National Leniency (2 lags)	-0.0477***	-0.0669***	-0.0659***	-0.0629***
	(0.0149)	(0.0202)	(0.0201)	(0.0201)
1st EU Leniency (2 lags)	0.0337**	0.0252	0.0251	0.0249
	(0.0159)	(0.0186)	(0.0186)	(0.0186)
2nd EU Leniency (2 lags)	-0.0122	-0.0314*	-0.0313*	-0.0313*
	(0.0143)	(0.0173)	(0.0173)	(0.0173)
Leniency N. Country (2 lags)	0.0254*	-0.0093	-0.0091	-0.0082
	(0.0134)	(0.0163)	(0.0163)	(0.0163)
Single Market Program (2 lags)	-0.0293	0.0603	0.0598	0.0583
	(0.0193)	(0.0443)	(0.0443)	(0.0443)
PMR Index (2 lags, in logs	0.0961***	0.0660**	0.0657**	0.0646**
	(0.0285)	(0.0321)	(0.0321)	(0.0321)
GDP Trend (in logs, 1 lag)	0.0025	0.0060**	0.0060**	0.0059**
	(0.0023)	(0.0028)	(0.0028)	(0.0028)
Import penetration (in logs, 1 lag)	-0.2349***	-0.2564***	-0.2563***	-0.2561***
	(0.0141)	(0.0184)	(0.0184)	(0.0184)
Imports (in logs, 1lag)	0.1909***	0.2178***	0.2178***	0.2177***
	(0.0187)	(0.0253)	(0.0253)	(0.0253)
Time dummies	x	x	x	x
Constant	-9.0697***	-9.9887***	-9.9864***	-9.9794***
	(0.6744)	(0.8827)	(0.8826)	(0.8825)
Wu-Hausman Test	1.0	1.0	1.0	1.0
Sargan Test	-	0.62	0.73	0.00
Observations	2389	1640	1640	1640

Robust Standard errors are in brackets
*Significant at 1% ***, significant at 5 % ** , significant at 10% **
Instruments used: Column (1) OECD Leniency,
Column (2) + "**Welfare**"(Klingemann et al. 2006, p. 163)
Column (3) + "***Welfare State Limitation***"(Klingemann et al. 2006, p. 158),
Column (4) + "**Planeco**"(Klingemann et al. 2006, p. 163)
See similar Table in Buccirossi et al. (2009, p. 40, Table 4)

Table 2.8: Leniency and Timing

	ln(PCM) Fixed Effects (1)	ln(PCM) Fixed Effects (2)	ln(PCM) Fixed Effects (3)	ln(PCM) Fixed Effects (4)	ln(PCM) Fixed Effects (5)	ln(PCM) Fixed Effects (6)
National Leniency	-0.0293**					
	(0.0143)					
National Leniency (1 lag)		-0.0264**				
		(0.0127)				
National Leniency (2 lags)			-0.0378**			
			(0.0160)			
National Leniency (3 lags)				-0.0392**		
				(0.0167)		
National Leniency (4 lags)					-0.0336*	
					(0.0171)	
National Leniency (5 lags)						-0.0440**
						(0.0220)
1st EU Leniency (2 lags)	0.0463**	0.0469**	0.0447**	0.0255	0.0228	0.0073
	(0.0220)	(0.0219)	(0.0219)	(0.0236)	(0.0238)	(0.0243)
2nd EU Leniency (2 lags)	-0.0180	-0.0167	-0.0155	-0.0160	-0.0344**	-0.0270*
	(0.0167)	(0.0155)	(0.0153)	(0.0153)	(0.0168)	(0.0161)
Leniency N. Country (2 lags)	0.0425*	0.0362*	0.0301	0.0263	0.0287	0.0308
	(0.0217)	(0.0218)	(0.0226)	(0.0223)	(0.0216)	(0.0209)
Single Market Program (2 lags)	-0.0511***	-0.0563***	-0.0576***	-0.0573***	-0.0527***	-0.0206
	(0.0191)	(0.0196)	(0.0202)	(0.0209)	(0.0197)	(0.0191)
PMR Index (2 lags, in logs	0.1045**	0.1063**	0.1154**	0.1025*	0.0712	0.0703
	(0.0495)	(0.0488)	(0.0511)	(0.0525)	(0.0530)	(0.0545)
EU 2004 enlargement (2 lags)	0.0335	0.0235	0.0151	0.0198	0.0406	0.0370
	(0.0304)	(0.0296)	(0.0299)	(0.0293)	(0.0308)	(0.0306)
New EU member in 2004 (2 lags)	0.0084	0.0225	0.0390	0.0705*	0.0788*	0.0830*
	(0.0410)	(0.0410)	(0.0431)	(0.0424)	(0.0430)	(0.0450)
GDP Trend (in logs, 1 lag)	0.0013	0.0016	0.0019	0.0023	-0.0005	0.0026
	(0.0030)	(0.0030)	(0.0031)	(0.0033)	(0.0030)	(0.0052)
Import penetration (in logs, 1	-0.2209***	-0.2210***	-0.2225***	-0.2261***	-0.2406***	-0.2466***
	(0.0552)	(0.0551)	(0.0548)	(0.0580)	(0.0586)	(0.0656)
Imports (in logs, 1 lag)	0.1824***	0.1838***	0.1858***	0.1821***	0.1961***	0.2017***
	(0.0509)	(0.0509)	(0.0505)	(0.0539)	(0.0546)	(0.0629)
Time dummies	x	x	x	x	x	x
Constant	-8.6137***	-8.6480***	-8.7428***	-8.7116***	-9.2522***	-9.4679***
	(2.1621)	(2.1620)	(2.1423)	(2.2810)	(2.3053)	(2.6266)
R^2	0.1623	0.1615	0.1641	0.1688	0.1858	0.1737
Observations	2531	2531	2531	2389	2298	2098

Robust Standard errors are in brackets.
*Significant at 1% ***, significant at 5 % ** , significant at 10% **

Table 2.9: Leniency Programs and the Legal System

	ln(PCM) Pooled OLS (1)	ln(PCM) Pooled OLS (2)	ln(PCM) Pooled OLS (3)	ln(PCM) Pooled OLS (4)
National Leniency (2 lags)	-0.0308***	-0.0381**	-0.0533***	-0.0399**
	(0.0096)	(0.0189)	(0.0196)	(0.0201)
English Legal System	-1.5535***	-1.5485***	-1.2878***	-1.3077***
	(0.2230)	(0.2210)	(0.2488)	(0.2493)
German Legal System	-0.4732**	-0.4702**	-0.5863**	-0.5788**
	(0.2254)	(0.2250)	(0.2385)	(0.2409)
Scandinavian Legal System	-1.1690***	-1.1700***	-1.0293***	-1.0441***
	(0.1569)	(0.1566)	(0.1719)	(0.1722)
Eng. Legal Sys. x Leniency		0.0122	-0.0081	-0.0215
		(0.0207)	(0.0215)	(0.0217)
Ger. Legal Sys. x Leniency		-0.0190	0.0096	-0.0029
		(0.0239)	(0.0281)	(0.0315)
Sca. Legal Sys. x Leniency		0.0424*	0.0625***	0.0489**
		(0.0231)	(0.0224)	(0.0230)
PMR Index (2 lags, in logs)			0.1290***	0.1315***
			(0.0342)	(0.0342)
Single Market Program (2 logs)			-0.0457**	-0.0624***
			(0.0190)	(0.0203)
EU 2004 enlargement (2 lags)			0.0352	0.0429
			(0.0255)	(0.0267)
New EU member in 2004 (2 lags)			0.0738**	0.0608*
			(0.0324)	(0.0357)
1st EU Leniency (2 lags)				0.0428***
				(0.0142)
2nd EU Leniency (2 lags)				-0.0214
				(0.0163)
Leniency N. Country (2 lags)				0.0286*
				(0.0150)
GDP Trend (in logs, 1 lag)	0.0043**	0.0041*	0.0018	0.0019
	(0.0021)	(0.0021)	(0.0023)	(0.0022)
Import penetration (in logs, 1	-0.2415***	-0.2404***	-0.2165***	-0.2194***
	(0.0344)	(0.0343)	(0.0369)	(0.0373)
Imports (in logs, 1 lag)	0.2011***	0.2020***	0.1849***	0.1868***
	(0.0331)	(0.0332)	(0.0343)	(0.0347)
Industry Country dummies	x	x	x	x
Time dummies	x	x	x	x
Constant	-9.0564***	-9.0490***	-8.4881***	-8.5895***
	(1.3792)	(1.3777)	(1.4421)	(1.4605)
R^2	0.8489	0.8495	0.8569	0.8577
Observations	2736	2736	2531	2531

Robust Standard errors are in brackets.
*Significant at 1% ***, significant at 5 % ** , significant at 10% **
See similar Table in Buccirossi et al. (2009, p. 41 Table 5)

3 Endogenous Firm Heterogeneity, ICT and R&D Incentives[1]

3.1 Introduction

The economic literature has provided robust evidence indicating that the adoption of information and communication technologies (ICT) has positively affected productivity at aggregate and firm levels (Draca et al. 2007, Crandall et al. 2007, Van Ark et al. 2008, Jorgenson et al. 2008), which has been used as a starting point for many studies investigating particular effects of ICT (e.g. Bertschek and Meyer 2010). Given that strong impact of ICT it does not surprise that the literature has shown that the benefits are not equally distributed among adopting firms (e.g., Chun et al . 2008, p. 132, Bresnahan et al. 2002, p. 343). As it is shown, some firms can take advantage of those benefits better than others such that the adoption of ICT represents a source of heterogeneity (see, for heterogeneity due to organization and IT use, Bresnahan et al. [2002, p. 343]; see Chun et al [2008, p. 132]) that might have an impact on other relevant variables as, for instance, aggregated productivity (Chun et al. 2008, pp. 132, 133-134).

This chapter empirically studies how the adoption of ICT affects firm heterogeneity and how such (ICT induced) heterogeneity impacts on R&D incentives. The analysis is based on two established results from the empirical literature on the analysis of productivity at the firm level. The first result shows that there exist large differences in productivity (see, Bartelsman and Doms 2000, for a survey as well as Syverson 2004, for an analysis of heterogeneity in productivity). Moreover, those differences explain according to Chun et al. (2008, p. 132), how "creative destruction"(Chun et al. 2008, p. 132) works, a

[1]This chapter is based on joint work with Daniel Cerquera, Centre for European Economic Research (ZEW), Mannheim. This chapter is based on and published in an earlier discussion paper version that differs slightly (Cerquera and Klein 2008). Versions of this work have been presented at different conferences: 30th Hohenheimer Oberseminar at the University of Nuremberg 2008, the EU KLEMS Final Conference at the Universtiy of Groningen 2008, the 35th Conference of the European Association of Research in Industrial Economics (EARIE), Toulouse 2008, and the Congress of the European Economic Association, Barcelona 2009, the Comparative Analysis of Enterprise Data 2009 Conference, Tokio. We would like to gratefully acknowledge the comments and suggestions from participants and anonymous referees. Moreover we would like to thank to Irene Bertschek for valuable comments and especially Jörg Ohnemus for many valuable comments as well as explanations. All errors are mine.

term that has been introduced into the debate by Schumpeter (1942/1947)[2] where more productive firms grow faster, exhibit a higher probability of survival and lead to market exit of low productivity firms (Chun et al. 2008, p. 132, as well as, for a discussion on the role of productivity, and its particular impact Foster et al. 2008). The second result in the literature has documented how the adoption of ICT has a significant, positive impact on productivity at the firm level (see, Draca et al. 2007, for a survey). Although the latter suggests, taking into account the study of Chun et al. (2008) that ICT impacts firm heterogeneity, the main contribution of this chapter is to account for the role of ICT on specific measures of firm heterogeneity.

If, as shown by the study of Chun et al. (2008), the adoption of ICT is expected to affect heterogeneity, and heterogeneity in turn explains "ongoing creative destruction"(Chun et al. 2008, p. 132), then the estimated ICT induced heterogeneity should be also related to additional firm strategies relevant for firm survival (see, studies discussing the impact of heterogeneity measures on firm strategies, Acemoglu et al. 2003, Acemoglu et al. 2007, Aghion and Griffith 2005). The present analysis empirically assesses the impact of the recovered ICT induced heterogeneity on one of such strategies: firm specific R&D incentives. Even though firm level competitiveness and survival depends on many factors, it has been widely recognized that innovative efforts depend on the competition in an industry (Aghion et al. 2005, Aghion and Griffith 2005). In the literature, R&D incentives are viewed as strategies that allow firms to gain advantages due to positive effects on firm level productivity (Griliches 1995, Crepon et al. 1998, Hall et al. 2009). This chapter investigates whether R&D incentives react to ICT induced heterogeneity.

Our analysis investigates the impact of ICT on heterogeneity on a firm-level, in Germany. For this we use the ZEW ICT Survey (ZEW 2004, ZEW 2007, see, e.g., also using this survey and describing it similarly, Ohnemus 2007, p. 16, 2009, pp. 12-13, as well as Bertschek and Meyer 2010, p. 7). It provides us with the necessary information, for the years 2003 and 2006, in particular, regarding the ICT use of firms (see, also, Ohnemus 2007, p. 16, 2009, pp. 12-13, Bertschek and Meyer 2010, p. 7). For instance, a measure of ICT intensity is included that has been similar used by other authors (e.g., Bertschek et al. 2010, p. 7, Ohnemus 2007, p. 15). A set of variables showing the adoption of different ICT applications such as enterprise resource planning systems (ERP), supply chain

[2]The idea of the "process of Creative Destruction"(Schumpeter 1942/1947, p. 83) has been discussed first by Schumpeter (1942/1947, pp. 81-86) and is since then a basic concept and fixed term, in economics. Therefore, using the term *creative destruction* we do not refer to Schumpeter (1942/1947) in the following explicitly, but set it in italics or call it Schumpetrian *creative destruction*. Consider that we refer, in the whole thesis to the revised 2nd edition of Schumpeter (1942/1947) in 1947 using its page information, which is to a large degree only a reprint, however the relevant argument goes back to 1942.

management (SCM) is also available in the data (other studies use this survey information as well, e.g., Engelstätter 2009, p.10). Additionally, the data include information on the innovative inputs (i.e. R&D) and outputs (i.e. innovations introduced to the market) of the sampled firms.

Given our particular heterogeneity measure, which is firm-specific and captures individual deviations of each particular firm's productivity from the industry productivity median,[3] this chapter shows that ICT has a robust, positive impact on firm heterogeneity only when ICT is used intensively *and* jointly with specific ICT applications. That is, through their use of ICT, firms are able to differentiate themselves (positively and negatively) with respect to other firms belonging to the same economic sector. This result is shown to be robust to different empirical strategies. In addition, the analysis also shows that ICT induced heterogeneity has a significant and positive impact on the incentives to innovate. In particular, ICT induced heterogeneity is shown to positively affect the decision to invest in R&D.

The intuition behind this result states that firms are able to deviate from their competitors in terms of productivity and through ICT only when the adopted infrastructure is large enough (i.e. intensive use of PC accompanied by specific ICT applications), which is similar to the complementarity argumentation between organization and ICT by Bresnahan et al. (2002, p. 343). In addition, Bresnahan et al. (2002, p. 343) considers similarly heterogeneity in the outcomes due to volatility of success since implementation of strategies is difficult. As firms in practice might employ several market strategies to differentiate themselves with respect to their competitors, it is not surprising that ICT induced heterogeneity is positively correlated with other market strategies such as R&D investments.

The chapter is, organized as follows. The second section discusses related literature. The third section presents the details of the empirical strategy. The fourth section summarizes the main results of the chapter. Finally, the fifth section concludes.

[3] SeeSyverson (2004, p. 539) and Acemoglu et al. (2007, p. 1772). In particular, our measure builds on the close "central tendency measure"(Syverson 2004, p. 539), which measures also deviations from an average productivity, however aggregated on an industry level. It is also similar to the commonly used "distance to the frontier"(Acemoglu et al. 2007, p. 1772), which uses instead of an average an high productivity level and is firm-specific.

3.2 Related Literature

This chapter is related with two strands of literature. First, it is related to the literature that documents the existence and persistence of firm heterogeneity in terms of productivity. The study most related to our work is Syverson (2004), who studies the impact of demand-side factors on differences in productivity levels. In particular, he can show that in industries that are subject to a low substitutability, which allows less efficient firms to protect themselves to some degree against competitors, are more heterogeneous in terms of productivity (Syverson 2004, p. 534).[4]

The literature has also considered widely the specific role of ICT on firm performance and productivity differences (e.g., Bresnahan et al. 2002, Brynjolfsson and Hitt 2003, Bloom et al. 2007). In that literature, ICT is shown to have a positive impact in a production function estimated, with an impact, however dependent on particular interactions, for instance with "organizational complements"(Bresnahan et al. 2002, p. 343). Different ICT intensity therefore lead to different productivity levels. However they are silent about the effect of ICT on the dispersion of the productivity distribution and do not recover the impact on firm strategies.

This chapter presents a measure of firm heterogeneity that explicitly accounts for the differences in productivity, allowing the analysis of the role of ICT use on firm heterogeneity. In particular, firm heterogeneity is defined similar to other commonly used measures in the literature as the difference of a firms productivity to the median productivity in our 14 industries defined (see, similar measures in Syverson 2004, Acemoglu et al. 2007).[5] In consequence, the adopted measure exhibits two main advantages with respect to the existing literature. On the one hand, it permits to directly account for the role of ICT on firm heterogeneity in a way that cannot be inferred from existing production function estimation. On the other hand, the economic literature has shown how firm heterogeneity (as previously defined) actually explains a great variety of strategic decisions at the firm level as the following literature review shows.

The second strand of literature related to the present chapter analyzes the impact of firm heterogeneity on firm strategies. Although there is a voluminous literature in this area, the

[4] However, the literature on differences in productivity is voluminous. One detailed survey on supply side factors on differences in productivity, also Syverson (2004) refers to is Bartelsman and Doms (2000).

[5] In particular, our measure is close to the "central tendency measure"(Syverson 2004, p. 539), which measures also deviations from an average productivity, however aggregated on an industry level, or also similar to the commonly used "distance to the frontier"(Acemoglu et al. 2007, p. 1772), which uses instead of an average an high productivity level.

relevant work for the present chapter corresponds to the analyses that considered similar measures of firm heterogeneity from an empirical perspective.

More specifically, Acemoglu et al. (2007) uses the concept "distance to the frontier"(Acemoglu et al. 2007, p. 1772) (i.e. a measure of heterogeneity) which captures the difference in productivity of a specific firm to the leading firms in the same industry either in the same country or in a benchmark country (Acemoglu et al. 2007, p. 1772).[6] Using this concept, they investigate the relationship between "diffusion of new technologies and the decentralization of firms"(Acemoglu et al. 2007, p. 1759). Their findings reveal interesting interrelations and in particular the position of firms matters, with efficiency being correlated to decentralization (Acemoglu et al. 2007, p. 1760).

In a sequence of papers, Acemoglu et al. (2003), Aghion et al. (2005), Acemoglu et al. (2006) and Aghion and Griffith (2005) use similar measures of heterogeneity in order to study, among other topics, the relationship between innovation, entry, credit constraints and competition. Essentially, these papers highlight the role of firm heterogeneity as a main driver of industry evolution.[7]

In a different approach, Chun et al. (2008) provides a panel data investigation for the US and estimate the impact of ICT use on firm heterogeneity. They find a positive correlation between heterogeneity in firm performance and the use of ICT (Chun et al. 2008, p. 132). Moreover, they also find a positive relationship between this heterogeneity and productivity (Chun et al. 2008, p. 132). Interestingly, they claim this heterogeneity to be a "measure of ongoing creative destruction"(Chun et al. 2008, p. 132) describing industry dynamics (Chun et al. 2008, p. 132). However, their results can only be recovered at the industry level and do not permit the analysis of their impact on firm strategies. This paper contributes to this literature by explicitly considering the impact of ICT on productivity heterogeneity at the firm level, analyzing the consequences for specific firm strategies relevant to the above described "ongoing creative destruction"(Chun et al. 2008, p. 132), i.e. R&D incentives.

3.3 Empirical Strategy and Data

The interest of this chapter is twofold. First, the interest lies in the estimation of the impact of ICT on firms' heterogeneity, defined as the deviation from a productivity benchmark,

[6]See, e.g., Acemoglu et al. (2007, p. 1778) for an overview of these measures.

[7]See Bartelsman et al. (2008) for an analysis of industry evolution using similar measures of firm heterogeneity. See, also, Syverson (2004), using similar measures of heterogeneity as well.

which is as discussed below related to the study of Syverson (2004). Secondly, the analysis focuses on the impact of ICT induced heterogeneity on firm strategies regarding R&D. The underlying idea of analyzing the impact of the factors having an impact on the endogenous and these on a third factor, i.e. innovation is a common strategy in the literature, for instance also performed by Griffith et al. (2010). They analyze also in a two-stage approach first the impact of competition affecting policies on competition intensity and then the effect of competition intensity on innovation. Therefore, analysis contains two parts as explained below.

3.3.1 The Impact of ICT on Firm Specific Heterogeneity

3.3.1.1 Estimation Equation

The first part tries to uncover the effect ICT has on firms' productivity heterogeneity. The empirical setup is oriented at the analysis provided by Syverson (2004), but differs regarding our focus on ICT and other firm strategies on a firm level. However, we similarly first present the estimation equation and then discuss jointly the empirical strategy and the data similar to Syverson (2004), in particular regarding the productivity measures for the heterogeneity measures. To identify the impact of ICT on heterogeneity, we take account of several typical potential sources of bias. In particular, we consider the correct direction of the causality, which results in endogeneity using the typical mean of a different timing of the explanatory variables regarding the dependent variable (e.g., Aghion et al. 2009, p. 22, Buccirossi et al. 2009, p. 9). In addition, other factors having an impact on our measure of interests that are tackled considering as many of those other relevant means for the variable of interest (e.g., Syverson, 2004, p. 539, Aghion et al. 2009, p. 22, Buccirossi et al. 2009, p. 9).

In addition, the measurement of heterogeneity relies on computation of productivity that can be computed and defined differently, which leads to a high importance of consideration of each concept drawbacks of each concept to avoid concept dependent results (Syverson 2004, pp. 539-540). In particular, we estimate the following model, which is analogous to the model proposed by Syverson (2004, p. 539), however on a firm level, to analyze the impact on heterogeneity given different factors, he considers industry structural market power factors, that affect, with a similar notation for the different control vectors:

$$Heterogeneity_{i,t} = \beta_0 + \omega ICT_{i,t-1} + \beta_{ORG} X_{ORG_{i,t-1}} + \beta_P X_{P_{i,t-1}} + \beta_C X_{C_{i,t-1}} + u_i \quad (3.1)$$

The variable $Heterogeneity_i$ is defined as a firms deviation of industries' median productivity, which is equal to the industry level "central tendency measure"(Syverson 2004, p. 539), however without an averaged industry, but firm specific value and therefore similar to the commonly used firm-specific "distance to the frontier"(Acemoglu et al. 2007, p. 1772).[8] Importantly, we use, given the information we have, a lag of three years to ensure that we can identify the direction of the causality (e.g., similarly, Aghion et al. 2009, p. 22). The vector $ICT_{i,t-1}$ comprises the main explanatory variables explaining the firms' specific ICT use. The specific ICT impact is the main feature our analysis. To consider alternative important impacts on a firm's heterogeneity, we introduce three classes of control variables similar to Syverson (2004, p. 539), however mostly on a firm level, to take account of factors that impact the deviation from the average productivity. The first, the vector $X_{ORG_{i,t-1}}$ uses the rich information of the survey (ZEW 2004, ZEW 2007) and describes firm strategies regarding a firms' organization and processes, which aim to improve the competitiveness of the firm and similar used for instance by Bresnahan et al. (2002, p. 350). Those are possibly subject to a volatile outcome in productivity (Bresnahan et al. 2002, p. 343), such that according to the Syverson's (2004, p. 539) model, we consider this source of heterogeneity. Second, we use the idea of Syverson's (2004) work to take account, of those factors $X_{P_{i,t-1}}$ that allow a firm to exhibit some degree of market power and, therefore, also to allow it to deviate from average productivity (Syverson 2004, p. 539). Third, the vector $X_{C_{i,t-1}}$ includes firm specific control variables used in all specifications to ensure consistent estimation (firm size, exporting behavior, industry, East vs. West Germany).[9] Importantly, previous periods heterogeneity is controlled for as the literature denotes heterogeneity differences due to productivity differences to be persistent over time (e.g. Bartelsman and Doms 2000).

3.3.1.2 Data

Our estimations rely, in the largest part, on survey firm data, of the 2004 and 2007 ZEW ICT Survey (ZEW 2004, ZEW 2007), by the Centre for European Economic Research, ZEW, which offers a rich set of firm information (see, using and describing the data simi-

[8]The measure of "central tendency measure"(Syverson 2004, p. 539) is more similar regarding the benchmark, however aggregates observation on an industry level, the "distance to the frontier"(Acemoglu et al. 2007, p. 1772) uses a benchmark on a firm level, however with a different productivity group.

[9]See Syverson (2004, p. 539) also using the $X_{C_{i,t-1}}$ for additional, however different controls. The controls used are typical controls also used by various authors using the same survey for productivity and/or innovation estimations, with the same industry classification (Ohnemus 2007, Ohnemus 2009, Bertschek and Meyer 2010). Consider that the referred to authors not use exactly the same controls, but all do take account of location, one of exporting behavior, however with a ratio, (Ohnemus 2007) and two of the same industry controls (Ohnemus 2007, Bertschek and Meyer 2010).

larly, Ohnemus 2007, p.16, 2009, pp. 12-13, as well as Bertschek and Meyer 2010, p. 7).[10] To complement the information of the survey, we use information on average industries' capital intensity, industries' value added, industries' sales and industries' depreciation rates provided by the German statistical office (Statistisches Bundesamt 2010). Moreover, information regarding industry costs shares for production inputs is added from the EU KLEMS database, November 2009 release (EU Klems Consortium 2009)[11] and information on inflation and government bond rates from the OECD Reference Series (OECD 2010d) and the OECD Key Economic Indicators (OECD 2010a).

First we discuss, similar to Syverson (2004, p. 539) the construction of our heterogeneity measures. They are defined as the firms productivity deviation of the industries median productivity (we use the 14 defined industries of the ICT survey [See, e.g., Bertschek and Meyer 2010, p. 7 using the same survey with the same industry definitions]), which is similar as stated above to the industry level "central tendency measure"(Syverson 2004, p. 539) or also similar to the commonly used, firm specific, "distance to the frontier"(Acemoglu et al. 2007, p. 1772). For the underlying productivity, we follow Syverson (2004, pp. 539-540) in using different definitions of productivity (TFP, Labor Productivity) to take account of different potential shortcomings of the data as the base for the heterogeneity measures (Syverson 2004, p. 539), which are constructed using the data available from the ZEW ICT survey (ZEW 2004, ZEW 2007). All our measures are implemented in difference to Syverson (2004, p. 539) using both sales and value added as output measures, while he only considers value added. Sales is given in the survey data, value added is calculated with the survey info on sales minus the expenditures on materials by the surveyed firms (see, analogous to, Syverson 2004, p. 539). Similar to Syverson (2004, p. 539) and as it is done typically in the literature, labor productivity is defined as either sales or value added generated, normalized on a worker level and TFP is derived from a production function framework. Besides the two possible output measures (sales and value added) the measures of heterogeneity in TFP differ with regard to the underlying production functions "input elasticities"(Syverson 2004, p. 540) as in Syverson (2004, pp. 539-540), who uses those on an industry and a firm level, for which "cost shares"(Syverson 2004, p. 539) are used. In particular, given a typical Cobb Douglas production function, TFP, $A_{i,t}$, can be easily calculated, all other information given (output, inputs and their elasticities), as it is presented in Syverson (2004, p. 539). Information on Y output (value added or sales) as well as on the inputs labor, L, and intermediate inputs, M, are provided by the ICT

[10] Most of the surveys questions are retrospective and regard the years 2006 and respectively 2003.

[11] The EU KLEMS database (EU Klems Consortium 2009) provides an aggregation of 32 industries based on the NACE 2 digit classification. See O'Mahony and Timmer (2009) for a detailed description.

survey (ZEW 2004, ZEW 2007). Capital, C and the elasticities, however, are not available directly, but have to be calculated.

For capital, we use information of average "NACE two-digit capital per employee values"(Ohnemus 2009, p.15)[12] and calculate the firm specific value taking into account firms employees (Ohnemus 2009, pp. 13-15). Then we consider one period of capital depreciation[13] and add its current period's investment provided by the ICT survey (ZEW 2004, ZEW 2007), which is also conceptually similar to Ohnemus (2009, p. 15). Industry costs are derived from the EU KLEMS database (EU Klems Consortium 2009).[14] Firm costs, first use the available information for intermediate inputs as well as for labor of the ICT survey (ZEW 2004, ZEW 2007). These measures however are not stated by all firms and moreover, for the firms that stated this, the values seem to be rather imprecise. Second, to calculate capital costs, we follow Griffith et al. (2007, p. C163) who multiplies capital with "Yield on USA Government composite bond (10 Years), minus inflation rate, plus assumed depreciation of 7%."(Griffith et al. 2007, p. C163) to calculate capital costs (Griffith et al. 2007, p. 163). However we slightly change this with German information. In particular, for capital costs, we use the sum of the risk free interest rate (public German debt), the average percentage of capital consumption, decreased by German price increase (see, similarly Griffith et al. 2007, p. C163).[15]

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[12] Data from German statistical office (Statistisches Bundesamt 2010) using net capital at replacement costs divided by employees, see, Ohnemus (2009, pp. 13-15). We use the capital before the year of the investment and labor of the investment period as the previous periods is not available. However, we experimented with different timing of the capital, which did not change essentially. Ohnemus (2009, pp. 13-15) constructs similarly capital by computing in the same way an initial capital stock by using industry information regarding "capital per employee values multiplied by the number of employees"(Ohnemus 2009, p. 15) in the ICT survey (ZEW 2004, ZEW 2007). Moreover, he approximates capital depreciation, using the same industry information regarding the average capital intensity and depreciated capital. In particular, he also suffers from missing capital data in the survey. However, for some 2 digit industries there is no reliable information of capital and employees such that we suffer from missing values for some 2 digit industries. We construct the capital in current prices, but we have experimented also with deflators that do not change the results significantly.

[13] Analogous to Ohnemus (2009, p.14),"shares of capital consumption"(Ohnemus 2009, p. 14) with the period between 1991 to 2006 on an 2 digit industry level (see, Ohnemus 2009, p. 14). Data from German Statistical Office (Statistisches Bundesamt 2010), see Ohnemus (2009, p. 14). However, for some 2 digit industries there is no reliable information of capital and employees such that we suffer from missing values for some 2 digit industries

[14] In particular, we use information on Intermediate inputs at current purchasers' prices (mill. Euros), Labor compensation (mill. Euros), and Capital compensation (mill. Euros). The database provides an EU KLEMS 2009 release provides an aggregation of 32 industries based on the NACE 2 digit classification. As for some industries only an aggregation of several two digit industries is given, we use the particular two digit information where available, but use the closest aggregation in which the industry is included where not available.

[15] See Griffith et al. (2007, p. C163) and the similar capital cost construction in chapter 2. The long term interest rate and price increases are provided by the OECD Reference Series (OECD 2010d). However, in contrast to Griffith et al. (2007, p. C163) we use the German long term interest rate. Relative capital consumption rates are calculated as stated above. Inflation rate is given by the OECD Key Economic Indicators database (OECD 2010a).

The use of the different productivity definitions is done to take account of both conceptual and general problems of the measures discussed in depth in Syverson (2004, pp. 539-540) and particular problems with our data. In particular, Syverson (2004, p. 539), argues that value added measures are less biased due to large "interplant differences in intermediate input intensity"(Syverson 2004, p. 539) and he discusses regarding the elasticities of production inputs, in the TFP calculation that the use of "plant-specific elasticities in TFP1 better account for within-industry technology differences [..], but are potentially vulnerable to measurement error"(Syverson 2004, p. 539). We account for these problems, however as we use survey data, we face the disadvantage that some information in the ICT survey on expenditures, i.e. information on intermediate inputs, is rather imprecise such that interpretation of value added has to be cautious. Therefore, we trust more in the output in sales as we can control for industry effects in our estimation, which should reduce some of this feared bias of Syverson (2004, p. 539). In addition to this imprecision of some of the relevant variables (i.e. firm specific cost of intermediate input use and firm specific labor costs) together with a lot of imputation (i.e. firm specific capital costs), we fear imprecision in the firm specific cost shares. Given the concerns of Syverson (2004, pp. 539-540) regarding their precision in general, we trust clearly more in the industry specific elasticities.

The main explanatory variables are controls for ICT use. In particular, we control for firms' general ICT intensity, measured in % of employees working mainly at a PC, which is provided by the ZEW ICT survey (ZEW 2004, ZEW 2007).[16] In addition, information on firm specific software systems is available as well, capturing whether a firm uses either intense or partially Enterprize Resource Planning (ERP) or Supply Chain Management (SCM) software (other studies use this survey information as well, e.g., Engelstätter 2009, p.10).[17] These specific software systems are added to the estimation, because they are expected to have an important impact on the processes within a firm and require mostly large investments. We claim that this impact may be large, however, dependent as it is typical for ICT on other factors such that the outcome is uncertain (see similarly, for ICT as GPT in general, Draca et al. 2007, pp. 105-106). In particular, to capture the interrelation

[16]See similarly Bertschek et al. (2010, p. 7) or Ohnemus (2007, p. 15), calling this variable similarly "The share of workers predominately working at a PC"(Bertschek et al. 2010, p. 7) ,"share of employees working mainly at a computerized workplace"(Ohnemus 2007, p.16).

[17]The variables are coded in three steps, with two indicating intense use, one partial use and zero no use.

of these software applications with the general ICT strategy, we use interaction effects of the described firm specific software systems and the general ICT intensity of a firm.[18]

Beside the main explanatory variables, we take other firm strategies into account that may be correlated with volatility in the success of implementation, which may induce heterogeneity (Bresnahan et al. 2002, p. 343). This clearly takes account on an argument by Syverson (2004, p. 541) to take into account other factors having an impact on his heterogeneity measures. In particular, we consider two organizational strategies also used by Bresnahan et al. (2002, p. 350) for which information on their use (% of employess affected) is provided in the ICT survey (ZEW 2004, ZEW 2007). These strategies may be, besides ICT strategies, an alternative way for firms to differentiate themselves (Bresnahan et al. 2002, p. 343). The first are so called "quality circles"(Bresnahan et al. 2002, p. 350), which we denote QC in the estimations. The second is the implementation of "self-managing teams"(Bresnahan et al. 2002, p. 350), which we call in the following self responsible units or SRU. We assume, given the argument of Bresnahan et al. (2002, p. 343) that this strategies affect the volatility of the outcomes (Bresnahan et al. 2002, p. 343).

Another factor, which may explain heterogeneity, is as discussed in the literature review, market power by a firm (Syverson 2004).[19] We can only control partially for this factor. Our strategy is that we compute the size of sunk costs within a industry as Syverson (2004, pp. 541-542) does. In particular, according to Syverson (2004, p. 542), who follows Sutton (1991), sunk costs are are calculated as: "the market share of an industry's median-size plant multiplied by the capital-output ratio for the industry"(Syverson 2004, p. 542).[20]

Several additional, typical controls are used in the estimation (see, ZEW 2004, ZEW 2007). Most importantly, we control for the previous periods heterogeneity (see, for persistence of

[18]See, the literature on ICT highlights many different important complementarities. For instance Engelstätter (2009) analyses those for the firm software we have (ERP,SCM), Bresnahan et al. (2002, p. 341) highlights "role of complementarities among information technology, workplace organization, and product innovation as drivers of the SBTC"(Bresnahan et al. 2002, p. 341), with "SBTC"(Bresnahan et al. 2002, p. 341) meaning "Skill-biased technical change"(Bresnahan et al. 2002, p. 340) .

[19]Syverson (2004) takes account of several typical market power factors that reduce the product substitutability.

[20]We calculate the industry's capital output ratio by information provided by the German Federal Statistical Office (Statistisches Bundesamt 2010, Statistisches Bundesamt 2010a) in the national accounts, providing information on industries aggregated capital, sales and value added at a NACE 2 digit industry level. The sales of the median sized firm is identified using the ICT survey (see, ZEW 2004, ZEW 2007). We assume that due to representativeness, the median of the industries is identified properly. The median sales are multiplied with the overall industry sales to derive the median market share. The measure of sunk costs is used in logs, to ensure the functional form and give less weight to potential outliers. Sources: Market Size in over sales is given by Statistisches Bundesamt (2010a) and value added as well as gross fixed assets by Statistisches Bundesamt (2010).

differences in productivity, Bartelsman and Doms 2000). Moreover, we control for firms' exporting behavior and location (West vs. East Germany) as well as a set of 14 industry dummies as similar done by other authors using this survey either for productivity or innovation analysis (e.g., Ohnemus 2007, Ohnemus 2009, Bertschek and Meyer 2010).[21]

3.3.2 The Impact of ICT Induced Heterogeneity on Firms' Research and Development Strategy

3.3.2.1 Estimation Equation

The second part of the analysis tries to test the hypothesis that ICT induced heterogeneity has an important impact on firms' strategies. In particular, we analyze whether ICT induced heterogeneity has an impact on firms' strategies regarding R&D. To identify the impact of ICT induced heterogeneity, we perform an general methods of moments instrumental variable estimation (see, for the analogous idea and similar strategy, Griffith et al. 2010, pp. 5-7). We estimate the following relationship, which follows a typical idea that, for instance, has been proposed by Griffith et al. (2010, pp. 5-7) to analysis the impact of a instrument on an innovation variable.[22] using a similar formulation of the two stage regression, however in a different setting:

$$Heterogeneity_{i,t} = f(X_{i,t-1}, ICT_{i,t-1}) \tag{3.2}$$

$$R\&D - Strategy_{i,t} = f(X_{i,t-1} + Z(Heterogeneity)) \tag{3.3}$$

The variable $R\&D - Strategy$ captures the percentage of employees engaged in R&D, provided by the ZEW ICT survey (ZEW 2004, ZEW 2007). This measure is proposed, for instance, by the OSLO manual (OECD and Eurostat 2005) in its section on "Other qualitative indicators of innovation activity"(OECD and Eurostat 2005, p. 99) claiming that this is in particular one of "supplementary measures of the innovation capability of the firm's knowledge stock and employees"(OECD and Eurostat 2005, p. 100). The heterogeneity measure uses one of the previously defined heterogeneity measures. We suppose that ICT has an impact on a firms' R&D strategy through its impact on Heterogeneity. $ICT_{i,t-1}$ is used as an instrument and captures all ICT related controls. X_i captures a set of R&D

[21] Consider that the referred to authors not use exactly the same controls, but all do take account of location, one of exporting behavior, however with a ratio, (Ohnemus 2007) and two of the same industry controls (Ohnemus 2007, Bertschek and Meyer 2010).

[22] See that there is a large literature, which explains how and why innovations are implemented. See, for instance, the studies of Peters (2009), Hottenrott and Peters (2009), Bertschek and Meyer (2010), or Polder et al. (2009).

relevant control variables similar to the standard variables also used similarly in other studies regarding innovation (e.g., using partially the same controls, Peters 2009, Hottenrott and Peters 2009, Bertschek and Meyer 2010), as well as important general controls, ensuring a consistent estimation. To uncover the impact of ICT induced heterogeneity, we use an instrumental variable estimation.

3.3.2.2 Additional Controls and Data

In addition to previously mentioned control variables, we consider several R&D specific controls that are available in the ZEW ICT Survey (see, ZEW 2004, ZEW 2007).[23] In particular, we exploit, similar to other studies using this survey (e.g., Bertschek and Meyer 2010, pp. 6-7), the information whether firms innovated (process or product innovations) in the previous periods or the information on the qualification of the employees (see, e.g., for controlling identically for past innovation and the qualification structure Bertschek and Meyer 2010, pp. 6-7).[24] Furthermore, we control whether the observed firm is the subsidiary of another enterprise, for which we use the same variable as Hottenrott and Peters (2009, p. 13) in a similar survey, who claim it to be an indicator of less financial restrictions. Additionally, controls that should ensure a consistent estimation as in the first estimation as other firm strategies (QC and SRU, Bresnahan et al. 2002, p. 343) are added. Moreover, other typical controls used similarly also by other other using this survey (e.g., Ohnemus 2007, Ohnemus 2009, Bertschek and Meyer 2010), or the similar Mannheim Innovation Panel (e.g. Peters 2009, Hottenrott and Peters 2009) as industry controls, location (West vs. East Germany), exporting behavior (yes/no) and former heterogeneity are included (see, for persistence of differences in productivity, Bartelsman and Doms 2000).[25]

[23]See for instance the study of Bertschek and Meyer (2010, pp. 6-7) also using the ICT survey and controlling therefore similarly to the determinants of innovation.

[24]See Bertschek and Meyer (2010, pp. 6-7) referring to the persistence in innovation argument by Peters (2009). We include the percentage of employees having a university degree. The effect of these employees is tested against employees with only a vocational degree and employees with a low qualification.

[25]Consider that the referred to authors not use exactly the same controls, but all do take account of location, one of exporting behavior, however with a ratio, (Ohnemus 2007) and two of the same industry controls (Ohnemus 2007, Bertschek and Meyer 2010).

3.4 Empirical Analysis

3.4.1 Descriptive Analysis

Table 3.1 provides information regarding productivity and its distribution in the six previously described productivity measures similarly to Syverson (2004).[26] This table reveals qualitatively similar results regarding the productivity distribution with the different measures as Syverson (2004, p. 534).[27] It is evident that productivity in terms of sales has always higher values than the corresponding productivity measure in value added as it is a residuum of sales minus material and labor costs. There are, in all different measures, significant differences within the productivity distribution, which is found similarly in the study of Syverson (2004, p. 534). We now compare analogous to Syverson (2004, p. 534), the particular differences in the productivity distribution we observe in our data by comparing the quantitative difference between the percentiles for our measures.[28] The difference between the 75% and 25% percentile has the average size of around one half of the mean value in both labor productivity measures and a little bit less in the first TFP measure (industry specific cost shares) considering the output in sales with a value of two thirds the mean, however the difference is larger for this particular TFP measure, considering output in value added.[29] Relative differences are larger for individual cost shares between these percentiles, however for both TFP measures, the value difference in the 90 and 10 percentile is a bit more than one time the mean, which is similar for the other measures as well, however, it seems to be more differentiated between measures considering sales and value added.[30] This can be observed also in the difference in the 95% and 5% percentile as well. Comparing those results with Syverson (2004, p. 534), shows that we find large differences in the productivity distribution as well.

Table 3.2 provides summary statistics on the main variables. The average firm has a size of 349 employees and 135 million Euros in sales. Regarding ICT use, it can be observed that on average, 48% of all employees are using mainly a PC at work. Moreover, ERP systems

[26] This table is similar to Syverson (2004, p. 535):Table 1. In particular it shows accordingly to Syverson (2004, p. 534) the productivity ranges between the 75-25, 90-10 and 95-5 percentiles. The analysis provided in this paragraph therefore follows similarly his comparison of the differences in the productivity distribution. We find similarly differences in the productivity distributions as he does.

[27] However Syverson (2004, p. 534) does not consider measures with sales as an output measure.

[28] See Syverson (2004, p. 534) comparing similarly the difference in the percentiles (75-25, 90-10 and 95-5 percentiles), however, he only considers output in value added and differently shows ratios.

[29] See as mentioned above that we similarly compare the disperion of the productivity distribution as in Syverson (2004, p. 534), however in adaption for our data.

[30] See as mentioned above that we similarly compare the disperion of the productivity distribution as in Syverson (2004, p. 534), however in adaption for our data.

are used more intensively than SCM systems (1.141 intensity of ERP use vs. 0.634 intensity of SCM use). We also see that there is sufficient use of given organizational strategies with around 21% of all employees in firms using QC and 24% working in SRU (organizational strategy variables capture % of employees affected). The size of sunk costs is rather low. However, it is comparable to the sunk costs calculated by Syverson (2004, p. 540, Table 2). In addition, the table reveals information regarding the qualification structure (22% high qualified), innovative outputs (64% of firms have product innovations between 2001-2003 and 75% have process innovations between 2001-2003), as well as inputs.

Table 3.3 shows that specific ICT use by the firms is important. The analysis of the six heterogeneity in productivity measures presented shows a correlation for all of the heterogeneity measures with ICT intensity. The observed impact is less clear regarding ERp. Positive as well as negative impacts on the average heterogeneity are observable. Similarly, firms organizational strategy to delegate control to self-responsible units seems to be correlated positively with heterogeneity in some measures. The same is true for the measure of sunk costs. If those sunk costs are higher than the average, they seem to increase the labor productivity and TFP with industry cost share measures of heterogeneity but decrease the TFP measures with individual cost shares measured in sales. Clearly, these ambiguous results indicate that uncovering the impact of these variables requires econometric techniques considering different sources of impact on heterogeneity.

Regarding R&D, ICT provide an ambiguous picture. There seems to be a strong correlation of R&D personnel with a firms general ICT intensity (7% of firms below the median ICT intensity vs. 17% above the median ICT intensity); there does not seem to be a strong correlation with ICT systems. The organizational strategy of self-responsible units does not seem to have a strong impact as well. However, it is negatively correlated with R&D personnel (12% with those techniques vs. 13% without), and is correlated negatively with sunk costs. If those are lower than the median, this seems to be correlated with more R&D intensity (12% with a lower than the median sunk costs vs. 10% with higher ones).

3.4.2 Econometric Analysis

Table 3.4 shows the main results of the first part of the analysis regarding the impact of ICT on firm specific heterogeneity. In particular, the dependent variable corresponds to the absolute value of the deviation of a given firm's labor productivity with respect to its industry median in 2006. Labor productivity is defined as sales per employee, although alternative measures of productivity at the firm level are considered below. The results presented in table 3.4 are obtained by means of ordinary least squares (OLS) with robust standard errors.

Column 1 shows a baseline specification in order to control for the main characteristics at the firm level that might independently influence firms' heterogeneity. More specifically, we control for firm size measured as the logarithm of the number of employees, previously observed heterogeneity (identically defined for the year 2003), export activity, firm location and economic sector. Firm size positively affects firm level heterogeneity, implying a high variability in the performance of large companies, possibly due to their higher exposure to different markets. In turn, previously observed heterogeneity in 2003 explains a great proportion of the variation in firm heterogeneity observed in 2006. This result is consistent with the observation that firm level heterogeneity is persistent over time. In addition, export activity and firm location do not appear to have an independent impact on firm heterogeneity. Interestingly, the previous baseline results are robust over alternative specifications.

In order to consider the role of ICT in explaining firm heterogeneity, column 2 includes the intensity of ICT at the firm level, measured as the percentage of employees that work mainly with a PC.[31] The results show no independent impact of the intensity of ICT. This finding might be explained by the fact that the adoption of ICT in itself does not affect firm performance. Within firms, in order to benefit from the adoption of ICT, the adoption of alternative applications and/or alternative organizational designs might be required to exploit the existing ICT infrastructure.[32] This hypothesis is explored in column 3. In particular, the use of Enterprise Resource Planning (ERP) and Supply Chain Management (SCM) systems are included in the analysis. The variables for ERP and SCM take the value of 1 if the firm has adopted the system, and take the value of 2 if the firm explicitly considers its use as intensive. As before, the results show no independent impact of the intensity of ICT and/or the adoption of either ERP and/or SCM systems.

However, it is possible that in order to affect firm heterogeneity, the interaction between the intensity of ICT and the adoption of ERP systems represents the relevant measure (i.e. complementarity). This is indeed the case presented in column 4. In particular,

[31]See similarly Bertschek et al. (2010, p. 7) or Ohnemus (2007, p. 15), calling this variable similarly "The share of workers predominately working at a PC"(Bertschek et al. 2010, p. 7) ,"share of employees working mainly at a computerized workplace"(Ohnemus 2007, p.16).

[32]See, the literature on ICT highlights many different important complementarities. For instance Engelstätter (2009) analyses those for the firm software we have (ERP,SCM), Bresnahan et al. (2002, p. 341) highlights "role of complementarities among information technology, workplace organization, and product innovation as drivers of the SBTC"(Bresnahan et al. 2002, p. 341), with "SBTC"(Bresnahan et al. 2002, p. 341) meaning "Skill-biased technical change"(Bresnahan et al. 2002, p. 340).

the results show that when the intensity of ICT is high enough, the adoption ERP system positively affects firm level heterogeneity. That is, the positive coefficient of the interaction term (0.1587) compensates the negative coefficient on the intensity on the SCM systems (-0.0726). Column 5 follows the same analysis with respect to the use of SCM systems and shows equivalent results. Finally, column 6 introduces both (ERP and SCM) systems and shows, as before, that with a high intensity of ICT use, the adoption complementary ICT systems/applications positively affects firm level heterogeneity. However, in this specification the level of the ICT intensity with SCM slightly goes beyond the 10 % level, which may also be due to collinearity with the ERP variables.[33] Interestingly, the results presented in table 3.4 are robust to the introduction of previously observed heterogeneity along all specifications.

Table 3.5 extends previous results by considering alternative measures of firm level productivity (and therefore of firm level heterogeneity). A potential drawback from the analysis presented in table 3.4 corresponds to the use of labor productivity defined as sales per employee to construct our heterogeneity measure at the firm level. As labor productivity does not consider the intensity of the inputs' use at the firm level, our measure of heterogeneity might be overestimated. In order to control for the role of inputs' demand, we derive alternative heterogeneity measures based on one alternative measure of labor productivity and four additional measures of total factor productivity at the firm level.[34] The results are presented in table 3.5 and show the robustness of the conclusions from table 3.4 with respect to the impact of ICT on firm level heterogeneity defined from measures with productivity in TFP using industry specific cost shares. However, missing significance in heterogeneity with TFP measured with individual cost shares can be seen. We attribute this to the large noise in the measurement of individual cost shares in the ICT survey and the large dependence on various assumptions made. In addition, also the output measured in value added is less robust, however for column (4) with a p-value of 10.6 % we believe that taking into account the measurement problems of intermediate input goods, there seem to be an important correlation between ICT and heterogeneity. In addition we experimented with different constructions of capital that always lead to p-values slightly

[33] We use the SCM application in the following as it is more robust along the other measures.

[34] The productivity measures used to construct firm specific heterogeneity presented in columns 1 to 6 are: i) labor productivity (sales per employee); ii) labor productivity (value added per employee); iii) total factor productivity (with respect to sales using sector specific inputs' demand); iv) total factor productivity (with respect to value added using sector specific inputs' demand); v) total factor productivity (with respect to sales using firm specific inputs' demand); and vi) total factor productivity (with respect to value added using firm specific inputs' demand).

above or below the 10% level.[35] Table 3.6 extends the analysis by considering the role of demand (sunk cost) and supply factors (QC and autonomous teams within the firm) and shows the same qualitative results as in table 3.5, although the size of the coefficients is reduced.[36] The pattern in column (4) is the same as in the previous table. We think, that given the measurement problems, this correlation seems to support our hypothesis. However, we trust most in output measured in sales and heterogeneity in labor productivity and tfp measured with industry specific cost shares, because these measures impute the least information and do rely that much on the unprecise items in the survey.

In sum, the results of table 3.4, 3.5 and 3.6 show that ICT affects firm heterogeneity only when it is used intensively and jointly with particular ICT systems/applications. These results can be shown in some alternative measures of productivity (i.e. TFP with industry specific cost shares that we believe takes best account of the shortcomings of the data we have) that, in our framework, define firm level heterogeneity. Moreover, the results imply that if ICT impacts productivity positively and, in addition, induces firm heterogeneity, it could be argued that ICT represents a source of volatility that might stimulate the "process of Creative Destruction" (Schumpeter 1942/1947, p. 83), which is also discussed in Chun et al. (2008).[37] If this is the case, firms' optimal strategies should react accordingly, specially with respect to strategies that can provide a competitive advantage. One of these strategies corresponds to the firms' R&D initiatives. The second part of the analysis regarding the impact of ICT induced heterogeneity on the firms' R&D strategy is presented in table 3.8, following the two stage approach described in section 3.3.2. For this estimation we use the heterogeneity measure relying on industry specific cost shares that we believe to be theoretical as well as practical, given the measurement problems, to be most robust.

More specifically, following an instrumental variable approach, table 3.8 considers the impact of firm heterogeneity on R&D incentives defined as the ratio of R&D personnel to total employees in 2006, where ICT variables act as instruments. The results of the validity of the first stage are shown in table 3.7. In particular, column 1 shows a positive impact

[35]Column(4) values are only slightly above the critical 10% significance level (10.6%) such that we interpret the coefficients as supporting the hypothesis. Moreover, we experimented with different assumptions regarding the capital construction, for instance a common value of 7% for depreciation as in Griffith et al. (2007, p. C163), which led to a p-value at 9% for cloumn (4) in 3.5.

[36]We also experimented with more measures (not presented here) substracting also labor costs from value added. These measure, however, are uncommon in the literatur, but show stronger significance also for TFP with firm specific elasticities. We think that one explanation of this may be reduced the measurement error induced due to firm specific cost shares, however, on the side the measure itself also relies on many unprecise information.

[37]Consider that I refer, in the whole thesis to the revised 2nd edition of Schumpeter (1942/1947) in 1947 using its page information, which is to a large degree only a reprint, however the relevant argument goes back to 1942.

of ICT induced heterogeneity on R&D incentives (coeff: 2.8391, std. error: 1.5662), after controlling for qualification structure, alternative firm strategies, export activity, firm location and economic activity. Columns 2 and 3 extend the previous specification by including information on whether the firm introduced product and/or process innovations between 2001 and 2003 in order to control for past experience in innovative activities. As expected, the coefficients on this set of dummy variables are positive, although insignificant. Interestingly, the impact of ICT induced heterogeneity on R&D incentives remain positive and significant along these two specifications.

In order to control for the effect of possible financing restraints, column 4 introduces the information whether a firm is a subsidiary of a larger holding. In particular, it shows that this negatively affects R&D incentives, while the coefficient of the impact of ICT induced heterogeneity remains unchanged. Finally, column 5 uses the full set of control variables. The results show that the impact of ICT induced heterogeneity on R&D incentives remains positive and significant (coeff: 2.7569, std. error: 1.5499). The reported p-values of the endogeneity and over-identification tests suggest the validity of the IV approach and the exclusion restriction in all specifications.

3.5 Conclusions

This chapter has studied how the adoption of information and communication technologies (ICT) affects firm heterogeneity and, thereby, contributes to the productivity driven selection mechanism that determines aggregate productivity growth within industries. Given the well documented existence of high and persistent productivity differences within industries (e.g., Syverson 2004), this paper attempts to specifically estimate the role of ICT on such firm heterogeneity. The results show that for the most relevant specifications using the most reliable measures, ICT has a robust, positive impact on firm heterogeneity only when ICT is used intensively *and* jointly with specific ICT applications. However, we cannot identify these effects for all measures, which we believe is due to measurement problems in some of the variables. In addition, the analysis showed that ICT induced heterogeneity has a significant and positive impact on the incentives to innovate. These results suggest that firm heterogeneity is a factor explaining firms' strategic decisions and that ICT exert an important and independent impact in generating such heterogeneity.

3.6 Appendix

Table 3.1: Heterogeneity in Productivity

Variable	Mean	Standard Deviation	Percentile differences		
			75-25	90-10	95-5
Labor Productivity (Sales)	0.25	1.35	0.14	0.35	0.59
Labor Productivity (Value Added)	0.14	0.33	0.07	0.19	0.35
TFP Industry Cost Shares (Sales)	1.36	1.44	0.55	1.41	2.35
TFP Industry Cost Shares (Value added)	0.95	1.45	0.57	1.34	2.40
TFP Individual Cost Shares (Sales)	0.74	0.59	0.62	1.07	1.37
TFP Individual Cost Shares (Value added)	0.44	0.49	0.26	0.56	0.87

Sources: The sample includes 4,400 observations from the ZEW-ICT Survey of 2007 (ZEW 2007).
Auxiliary data sources are usedas described above
(EU Klems Consortium 2009, Statistisches Bundesamt 2010) as well as own calculations.
Based on Syverson (2004, p. 535):Table 1.

Table 3.2: Summary Statistics

Variable	**Mean**	**Std. Dev.**	**Observations**
Total Employees 2003	348.923	1743.083	3989
Sales (in millions Euro) 2003	134.953	1372.114	3155
Capital (in million Euros)	31.029	218.152	2780
Material Inputs (in million Euros)	0.780	2.235	2606
% of Employees working (mainly) with PC	0.481	0.333	4008
% of High Qualified Employees	0.222	0.254	3624
Use of Enterprise Resource Planning	1.141	0.893	3822
Use of Supply Chain Management Software	0.634	0.78	3897
Organization: (QC)	0.209	0.333	3837
Organization: (SRU)	0.238	0.375	3908
Sunk Costs	0.001	0.004	6269
Product Innovation 2003-2001	0.644	0.479	3968
Process Innovation 2003-2001	0.749	0.434	3988
Subsidiary of a Firm Group	0.419	0.493	4019
Eastern Germany	0.299	0.458	6439
Exports 2003	0.518	0.5	4000

Sources: The sample includes 4,400 observations from the ZEW-ICT Survey of 2004 (ZEW 2004)

Table 3.3: Descriptive Statistics - Means and Standard Deviations

Variable:	Entire Sample	% of employees working with a PC: Above Median	% of employees working with a PC: Below Median	By ERP use: With	By ERP use: Without	SRU: With	SRU: Without	Sunk Costs: Above Median	Sunk Costs: Below Median
Sales (in millions Euro) 2003	134.953	139.583	130.551	203.463	12.704	208.898	64.731	123.142	83.901
	(1372.114)	(935.934)	(1719.003)	(1707.949)	(36.745)	(1273.683)	(1409.723)	(918.655)	(721.029)
Total Employees 2003	348.923	352.661	340.67	515.607	66.636	619.866	145.810	388.894	299.829
	(1743.083)	(1749.495)	(1730.536)	(2176.296)	(145.495)	(2561.806)	(843.100)	(1877.928)	(1611.012)
% of R&D personnel of total employees 2006	0.112	0.169	0.07	0.117	0.132	0.11	0.128	0.101	0.122
	(0.187)	(0.238)	(0.138)	(0.196)	(0.215)	(0.193)	(0.209)	(0.182)	(0.192)
Heterogeneity 2006 (Labor Productivity, Sales)	0.637	0.657	0.557	0.603	0.593	0.633	0.578	0.653	0.599
	(0.624)	(0.677)	(0.507)	(0.611)	(0.580)	(0.63)	(0.546)	(0661)	(0.562)
Heterogeneity 2006 (Labor Productivity, Value Added)	0.574	0.609	0.515	0.563	0.541	0.621	0.520	0.581	0.545
	(0.574)	(0.646)	(0.498)	(0.592)	(0.546)	(0.648)	(0.516)	(0.595)	(0.529)
Heterogeneity 2006 (TFP 1, Sales)	0.341	0.413	0.285	0.346	0.329	0.367	0.327	0.345	0.333
	(0.371)	(0.448)	(0.321)	(0.408)	(0.342)	(0.414)	(0.369)	(0.369)	(0.365)
Heterogeneity 2006 (TFP 1, Value Added)	0.520	0.576	0.489	0.536	0.511	0.549	0.514	0.543	0.496
	(0.474)	(0.541)	(0.445)	(0.509)	(0.460)	(0.509)	(0.484)	(0.478)	(0.464)
Heterogeneity 2006 (TFP 2, Sales)	0.495	0.555	0.465	0.477	0.546	0.517	0.495	0.488	0.497
	(0.492)	(0.569)	(0.494)	(0.496)	(0.582)	(0.529)	(0.520)	(0.528)	(0.449)
Heterogeneity 2006 (TFP 2, Value Added)	0.467	0.521	0.442	0.467	0.493	0.511	0.453	0.464	0.463
	(0.475)	0.564	(0.463)	(0.496)	(0.543)	(0.529)	(0.494)	(0.519)	(0.420)

Source: The sample includes 8,800 observations from the ZEW-ICT Survey of 2004 and 2007
(ZEW 2004, ZEW 2007).
Auxiliary data sources are used as mentioned in the text (EU Klems Consortium 2009, Statistisches Bundesamt 2010) as well as own calculations.

Table 3.4: Impact of ICT on Firm-Specific Labor Productivity Heterogeneity

Dependent Variable: *Firm Heterogeneity (Absolute deviation from Median of Labor Productivity 2006 (in Logs.))*	Ordinary Least Squares					
	(1)	(2)	(3)	(4)	(5)	(6)
% of Employees working with PC (*PCW*)		0.0063	0.0104	-0.1405*	-0.0783	-0.1715**
		(0.0559)	(0.0593)	(0.0799)	(0.0653)	(0.0834)
Supply Chain Management (*SCM*)			0.0016	-0.0726**		-0.0609**
			(0.0199)	(0.0295)		(0.0287)
Enterprise Resource Planning (*ERP*)			-0.0012		-0.0675**	-0.0413
			(0.0207)		(0.0318)	(0.0312)
$PCW \times SCM$					0.1697**	0.0973
					(0.0663)	(0.0676)
$PCW \times ERP$				0.1587***		0.1358**
				(0.0545)		(0.0564)
Heterogeneity 2003 (Labor Productivity, Sales)	0.5676***	0.5705***	0.5678***	0.5656***	0.5594***	0.5646***
	(0.0450)	(0.0449)	(0.0486)	(0.0479)	(0.0473)	(0.0484)
Total Employees (in logs)	0.0283***	0.0283***	0.0301**	0.0315***	0.0267**	0.0300**
	(0.0108)	(0.0109)	(0.0126)	(0.0121)	(0.0115)	(0.0125)
Constant	0.1739***	0.1702***	0.1488**	0.1995***	0.2172***	0.2237***
	(0.0574)	(0.0610)	(0.0661)	(0.0677)	(0.0642)	(0.0700)
Number of Observations	1134	1129	1066	1079	1109	1066
F-statistic	15.26	14.37	11.45	13.66	13.58	12.64
R^2	0.31	0.31	0.29	0.30	0.30	0.30

Robust standard errors are reported in parenthesis. Industry dummies, location and exporting behavior included.
*** Significant at 1%.** Significant at 5%. * Significant at 10%.

Table 3.5: ICT and Heterogeneity - Consistency for different measures

Dependent Variable: *Firm Heterogeneity 2006* *(Absolute deviation from Median Productivity, in logs)*	Ordinary Least Squares					
	HET LP (1)	HET LP VA (2)	HET TFP1 (3)	HET TFP1 VA (4)	HET TFP2 (5)	HET TFP2 VA (6)
% of Employees working with a PC (*PCW*)	-0.0783	-0.0162	0.0025	0.0016	-0.0121	0.0270
	(0.0653)	(0.0659)	(0.0515)	(0.0657)	(0.0754)	(0.0704)
Supply Chain Management (*SCM*)	-0.0675**	-0.0194	-0.0164	0.0074	-0.0190	0.0156
	(0.0318)	(0.0373)	(0.0216)	(0.0322)	(0.0292)	(0.0294)
$PCW \times SCM$	0.1697**	0.0999	0.1108**	0.1064(*)	0.0317	0.0280
	(0.0663)	(0.0695)	(0.0494)	(0.0657)	(0.0646)	(0.0656)
Heterogeneity 2003 (Labor Productivity, Sales)	0.5594***					
	(0.0473)					
Heterogeneity 2003 (Labor Productivity, Value Added)		0.4444***				
		(0.0596)				
Heterogeneity 2003 (TFP 1, Sales)			0.3650***			
			(0.0612)			
Heterogeneity 2003 (TFP 1, Value Added)				0.3590***		
				(0.0507)		
Heterogeneity 2003 (TFP 2, Sales)					0.5838***	
					(0.0512)	
Heterogeneity 2003 (TFP 2, Value Added)						0.4544***
						(0.0656)
Total Employees in logs	0.0267**	0.0308**	-0.0036	-0.0014	-0.0044	0.0051
	(0.0115)	(0.0141)	(0.0088)	(0.0121)	(0.0106)	(0.0111)
Constant	0.2172***	0.2083***	0.1695***	0.2742***	0.3161***	0.2051***
	(0.0642)	(0.0674)	(0.0449)	(0.0634)	(0.0620)	(0.0562)
Number of Observations	1109	890	721	721	684	684
F-statistic	13.58	6.48	8.33	6.31	14.61	7.47
R^2	0.30	0.23	0.29	0.24	0.40	0.30

Robust standard errors are reported in parenthesis. Industry dummies, location and exporting behavior included.
*** Significant at 1%.** Significant at 5%. * Significant at 10%. (only column (4)(*) Correlation at 10.6%.

Table 3.6: ICT and Heterogeneity - Supply and Demand Side Factors

Dependent Variable: *Firm Heterogeneity 2006 (Absolute deviation from Median Productivity, in logs)*	Ordinary Least Squares					
	HET LP	HET LP VA	HET TFP1	HET TFP1 VA	HET TFP2	HET TFP2 VA
	(1)	(2)	(3)	(4)	(5)	(6)
% of Employees working with a PC (PCW)	-0.0680	-0.0052	0.0192	0.0159	-0.0055	0.0361
	(0.0649)	(0.0658)	(0.0512)	(0.0655)	(0.0750)	(0.0703)
Supply Chain Management (SCM)	-0.0569*	-0.0139	-0.0181	0.0065	-0.0154	0.0236
	(0.0329)	(0.0385)	(0.0219)	(0.0327)	(0.0299)	(0.0297)
$PCW \times SCM$	0.1597**	0.0899	0.1006**	0.1030'	0.0192	0.0093
	(0.0674)	(0.0700)	(0.0496)	(0.0657)	(0.0650)	(0.0654)
Organization: (QC)	-0.0896**	-0.0465	-0.0049	-0.0461	-0.0480	-0.0659
	(0.0419)	(0.0433)	(0.0290)	(0.0435)	(0.0423)	(0.0417)
Organization: (SRU)	0.1039**	0.1572***	0.0773**	0.0641	0.0797**	0.0815*
	(0.0446)	(0.0539)	(0.0348)	(0.0449)	(0.0400)	(0.0455)
Sunk Costs	0.0133	0.0136	0.0252**	0.0193	0.0170	0.0183
	(0.0125)	(0.0141)	(0.0107)	(0.0123)	(0.0143)	(0.0147)
Heterogeneity 2003 (Labor Productivity, Sales)	0.5812***					
	(0.0473)					
Heterogeneity 2003 (Labor Productivity, Value Added)		0.4341***				
		(0.0592)				
Heterogeneity 2003 (TFP 1, Sales)			0.3479***			
			(0.0634)			
Heterogeneity 2003 (TFP 1, Value Added)				0.3472***		
				(0.0520)		
Heterogeneity 2003 (TFP 2, Sales)					0.5795***	
					(0.0522)	
Heterogeneity 2003 (TFP 2, Value Added)						0.4451***
						(0.0668)
Constant	0.4391***	0.4300***	0.4306***	0.4727***	0.5129***	0.4233***
	(0.1493)	(0.1568)	(0.1231)	(0.1452)	(0.1592)	(0.1600)
Number of Observations	1053	861	711	711	676	676
F-statistic	13.91	5.81	7.70	5.96	12.33	6.48
R^2	0.31	0.23	0.31	0.26	0.40	0.31

Robust standard errors are reported in parenthesis. Industry dummies, location, total employees and exporting behavior included.
*** Significant at 1%.** Significant at 5%. * Significant at 10%. (only column (4) ' Correlation at 12%).

Table 3.7: Impact of Firm-Specific Total Factor Productivity Heterogeneity on Firms' percentage of R&D worker; First Stage

	IV GMM				
	(1)	(2)	(3)	(4)	(5)
First Stage:					
Heterogeneity 2006 (TFP 1, Sales, in logs)					
% of Employees working with a PC (PCW)	0.0206	0.0204	0.0208	0.0176	0.0178
	(0.0677)	(0.0678)	(0.0679)	(0.0672)	(0.0674)
Supply Chain Management (SCM)	-0.0230	-0.0229	-0.0226	-0.0209	-0.0204
	(0.0266)	(0.0267)	(0.0266)	(0.0266)	(0.0266)
$PCW \times SCM$	0.1170**	0.1161*	0.1159*	0.1176**	0.1162*
	(0.0591)	(0.0593)	(0.0593)	(0.0596)	(0.0597)
Heterogeneity 2003 (TFP 1, Sales, in logs)	0.4108***	0.4107***	0.4106***	0.4105***	0.4103***
	(0.0821)	(0.0822)	(0.0823)	(0.0825)	(0.0827)
Product innovation 2003-2001		0.0114	0.0123		0.0147
		(0.0329)	(0.0354)		(0.0351)
Process innovation 2003-2001			-0.0043		-0.0060
			(0.0366)		(0.0367)
Investment	0.0074	0.0072	0.0074	0.0100	0.0100
	(0.0096)	(0.0095)	(0.0099)	(0.0108)	(0.0111)
% of High Qualified Employees	-0.0869	-0.0881	-0.0882	-0.0829	-0.0845
	(0.0913)	(0.0919)	(0.0922)	(0.0911)	(0.0920)
Subsidiary of Firm Group				-0.0338	-0.0347
				(0.0324)	(0.0324)
Organization: (QC)	-0.0188	-0.0215	-0.0215	-0.0189	-0.0221
	(0.0352)	(0.0355)	(0.0356)	(0.0353)	(0.0357)
Organization: (SRU)	0.0538	0.0536	0.0537	0.0596	0.0598
	(0.0418)	(0.0419)	(0.0420)	(0.0417)	(0.0419)
Constant	0.1564***	0.1505***	0.1528**	0.1687***	0.1652**
	(0.0568)	(0.0567)	(0.0623)	(0.0599)	(0.0656)
R^2	0.31	0.31	0.31	0.31	0.31
Number of Observations	481	481	481	481	481

Table 3.8: Impact of Firm-Specific Total Factor Productivity Heterogeneity on Firms' percentage of R&D worker; Second Stage

	IV GMM				
	(1)	(2)	(3)	(4)	(5)
Second Stage:					
% R&D employees of total Workforce					
Heterogeneity 2006 (TFP 1, Sales)	2.8391*	2.7547*	2.7678*	2.8182*	2.7343*
	(1.5662)	(1.5682)	(1.5695)	(1.5314)	(1.5325)
Heterogeneity 2003 (TFP 1, Sales)	-0.8684	-0.8349	-0.8400	-0.8485	-0.8147
	(0.6727)	(0.6725)	(0.6734)	(0.6545)	(0.6542)
Product innovation 2003-2001		0.1281	0.1354		0.1574
		(0.1280)	(0.1307)		(0.1325)
Process innovation 2003-2001			-0.0395		-0.0513
			(0.1402)		(0.1399)
Investment	-0.2328***	-0.2354***	-0.2337***	-0.2095***	-0.2092***
	(0.0382)	(0.0376)	(0.0397)	(0.0422)	(0.0435)
% of High Qualified Employees	1.3586***	1.3361***	1.3378***	1.3777***	1.3546***
	(0.3182)	(0.3148)	(0.3158)	(0.3151)	(0.3123)
Subsidiary of Firm Group				-0.2619*	-0.2743**
				(0.1382)	(0.1372)
Organization: (QC)	0.2208	0.1871	0.1881	0.2212	0.1842
	(0.1630)	(0.1664)	(0.1668)	(0.1605)	(0.1639)
Organization: (SRU)	-0.5071**	-0.5036***	-0.5027***	-0.4611**	-0.4541**
	(0.1970)	(0.1945)	(0.1950)	(0.1992)	(0.1969)
Constant	-3.7088***	-3.7620***	-3.7421***	-3.6097***	-3.6401***
	(0.3074)	(0.3033)	(0.3225)	(0.3175)	(0.3307)
Number of Observations	481	481	481	481	481
Wald Test	0.04	0.05	0.05	0.03	0.04
Hansens J-Test	0.38	0.37	0.37	0.48	0.47
R^2	0.03	0.06	0.05	0.05	0.07

Robust standard errors are reported in parenthesis. Industry dummies, location and exporting behavior included.
*** Significant at 1%.** Significant at 5%. * Significant at 10%. Significant at 15%

4 How Market Regulation Affects Network and Service Quality in Related Markets[1]

4.1 Introduction

How to regulate access prices in network industries has been one of the major issues of debate both in academic circles and among policy makers and regulators over the past 10 to 20 years. While most of the academic literature has initially focused on pricing issues in a static context (e.g., Armstrong 2002, Laffont et al. 1998), more recent contributions have also analyzed the relationship between access regulation and investment (e.g., Gans and King 2004, Foros 2004, Kotakorpi 2006, Vareda 2007).[2] Much of this literature concludes that stricter access price regulation usually has a negative impact on infrastructure investment, even though Vareda (2007) shows that the negative relationship between access price level and infrastructure investment only holds for quality enhancing investments but does not necessarily hold for cost-reducing investment. Common to all of these papers, however, is their shared focus in the incumbent's investments to replace or to extend the own network, i.e., the emphasis is on the investment incentives faced by existing infrastructure owners.

In contrast, a second stream of literature has focused on the entrants' investment incentives. In this literature, it is often argued that tighter access regulation initially encourages competitors to invest into complementary infrastructure which they can later use to build alternative networks in order to bypass the incumbent's bottlenecks. This so-called "ladder of investment"(Cave 2006, p. 224) idea has gained enormous support and popularity among regulators and policy makers, particularly in telecommunications markets (Cave and Vogelsang 2003, Cave 2006). While the "ladder of investment"(Cave 2006, p. 224) idea highlights the importance of complementary infrastructure, it ultimatively focuses also on network substitution and infrastructure competition.

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[1]This chapter is based on joint work with Justus Haucap, Heinrich-Heine-University of Düsseldorf, Düsseldorf Institute for Competition Economics (DICE). Versions of this work have been presented at different conferences and seminars: ZEW Internal Seminar, Mannheim 2008, the Conference of the Scottish Economic Society, Perth, 2008, the 29th Hohenheimer Oberseminar at the University of Marburg, 2008, the ITS 2008 - Biennial Conference of the International Telecommunications Society (ITS), Montreal, the 24th Congress of the European Economic Association (EEA), Barcelona 2009, the 36th Conference of the European Association of Research in Industrial Economics (EARIE), Ljubljana 2009 and the 20th ITS European Regional Conference of the International Telecommunications Society 2009 (ITS), Manama. We would like to thank all the participants and anonymous referees for comments and suggestions. All errors are mine.

[2]For an overview, see also Vogelsang (2003), Guthrie (2006), Cambini and Jiang (2009) and the contributions in Dewenter and Haucap (2007).

Our chapter focuses on a third type of investment, namely investment into the quality of complementary goods or services. To be more precise, we analyze the relationship between access regulation and investment incentives into both network and service quality if network usage and service provision are in a complementary relationship to each other. In contrast to the "ladder of investment"(Cave 2006, p. 224) perspective, we analyze complementary services which cannot substitute the original infrastructure but have to rely rather on access to this infrastructure.

An important example may be the (potential) regulation of broadband access markets, which also affects investment incentives for firms providing Internet services. Similarly, in railway markets, the investment incentives for train operating companies (into rolling stock and services) are also influenced by the regulation of access to the rail network (i.e., the tracks, stations, traction power, etc.). The same holds for airlines, the investment incentives of which are at least partially determined by airport regulation (slot allocation, landing fees, etc.) or for ports, where shipping companies have to purchase complementary pilotage, towage and discharging services and also pay dock dues.

From an empirical perspective, the relationship between access price regulation and investment is unclear. While a study by London Economics (2006) on behalf of the European Commission has tried to establish a strictly positive link between infrastructure regulation and investment, most other empirical studies come to ambiguous findings. Friederiszick et al. (2008), for example, find that access regulation discourages investment by new entrants, while they do not find effects for incumbent investments.[3] With this particular exemption, all other empirical studies rely on aggregate data, which does not allow them to analyze investment undertaken by incumbent operators and market entrants' investment separately.[4] Moreover, due to data limitations, no distinction is made between investment into complementary assets and investment into alternative (substitute) infrastructure (bypass). As we will argue in this chapter, this is a crucial distinction for empirical research, as the effects of access regulation on investment are fundamentally different for network operators and for firms that provide complementary services.

From a theoretical point of view, it is clear that, due to the vertical structure of the market, the organization or regulation of one market (usually the network market) does not only affect investment incentives in the particular market segment concerned, but also investment in any related upstream and downstream markets. Therefore, our model is related to

[3]For a survey, see Andersson et al. (2004) and Cambini and Jiang (2009).

[4]See, Vareda (2007,p. 14) claiming that they also not separate between the objects of investments, increasing efficiency and increasing demand.

Farrell and Katz (2000), who analyze innovation incentives in "systems markets"(Farrell and Katz 2000, p. 413) where two goods are complements, with one good being monopolized. They focus on the effects that result from an integration of the monopolized markets incumbent into the non-monopolized market when innovation only takes place in the non-monopolized market. Choi and Stefanadis (2001) extend the work of Farrell and Katz (2000) and analyze innovation in both markets. As they show, tying can be used to foreclose the market against entry if potential entrants need to innovate successfully in both markets.[5]

While our essay and its model is closely related to these two papers and their models, our focus is on the question of how regulation can affect investment. This question has neither been analyzed by Farrell and Katz (2000) nor by Choi and Stefanadis (2001), as their emphasis is on vertical integration and tying as means of market foreclosure. Moreover, we also extend the framework to goods which are only partially complementary. While our model is motivated by the current debate around investment incentives in network industries (see, Foros 2004, Kotakorpi 2006, Vareda 2007, for similar models, however we distinguish clearly between access and services and use a particular, different, consumer utility specification), the model presented in this chapter can also be applied to other industries where consumers have to purchase complementary products and at least one of these products is provided by a monopolist. Examples may be Internet services (such as *google*, *youtube* or *ebay*) and Internet access.

As we will show, regulation clearly has a negative effect on the incumbent network operator's incentives to invest into network quality, but this may be more than compensated by the increase in investment incentives for providers of complementary services. Moreover, we also show that tighter price regulation may not only reduce incentives to invest into network infrastructure, but investment incentives for complementary service providers may also *decrease* in the access price. This means, higher access prices may not only increase investment incentives for network operators, but also for firms that provide complementary services. This finding contrasts the conventional wisdom among regulators that tighter access price regulation spurs investment into complementary assets, as suggested by the "ladder of investment"(Cave 2006, p. 226) idea. In fact, we disentangle the overall effect

[5]The literature on complementary markets is voluminous. for instance also the classical model of Economides and Salop (1992) is related to our model, as similar market structures and complementarity between vertically related products are considered, however, they are interested in prices and not in quality, provision. However, they also consider the case that only one market is regulated. What, however, is similar, also to Farrell and Katz 2000, is that the firms are described in the basic model as independent firms.

of regulation on investment into a *direct effect* and an *effect*.[6] We show that a positive as well as negative impact on investment can be the result depending on (a) the relative cost of investment into network quality compared to investment into service quality and (b) the relative importance of network versus service quality for consumers. Moreover, our chapter demonstrates that a regulatory focus on how regulation affects the incumbent's incentives to undertake network replacement and extension investments and entrants' by-pass investments can be far too narrow if investment into the quality of complementary services is also important.

The remainder of this chapter is organized as follows: Section 2 introduces and analyzes the model when goods are perfect complements. We first compare network regulation to a non-regulated outcome if both the network and the service market are monopolized before we introduce downstream competition in section 2.2. Section 3 extends the model to partial complements before we discuss possible caveats and robustness in section 4. Section 5 summarizes our main results and concludes.

4.2 Investment Incentives with Perfect Complementarity

This section provides an analysis of the impact price regulation has on quality provision if there are two complementary products. Our analysis considers different market structures. In the first subsection we start with two monopolies and in the next we introduce a duopoly in the unregulated product market.

4.2.1 Upstream and Downstream Monopoly

4.2.1.1 Model Setup

This paper relates to the literature of access market regulation as Foros (2004), Kotakorpi (2006) or Vareda (2007), but uses also ideas of the modeling strategies of complementary markets as described by Farrell and Katz (2000) and Choi and Stefanadis (2001) constituted by two independent firms that offer in a vertical chain two complementary products.[7] Clearly, our model setup and its description is similarly to all those discussed models, however, the structure of the model description is most related to Foros (2004)

[6]See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

[7]However, all these models also consider vertical integration, but the main model is essentially the same.

and Vareda (2007).[8] Analogous to Farrell and Katz (2000, pp. 413, 417) and Choi and Stefanadis (2001, p. 56), the goods provided in both markets are “strictly complementary components”(Farrell and Katz 2000, p. 413). Examples are airline tickets and airport fees or taxes, harbor towage/pilotage services and docking fees or broadband access and Internet services. This means, the two products are assumed to be complements (as always in vertical industry structures) so that each market’s outcome depends on the other market’s outcome (see, for a similar complementarity setup, Farrell and Katz 2000, Choi and Stefanadis 2001).

We are interested similar to the models of Foros (2004), Kotakorpi (2006) and Vareda (2007), who consider the telecommunications sector explicitly, in the impact of regulation on investments and, therefore, compare the quality provision in a situation, under which market interference by a regulator, as in those models, happens only in one of those markets.[9]

Our markets are market A and market S, where market S represents to stay in our examples harbor pilotage, flight service or train service and A describes network access, landing fees, docking fees (the idea is closely related to the above models by Foros 2004, Kotakorpi 2006, Vareda 2007, but, differently, we distinguish clearly between independent provision of services and access, without any firm being active in both markets, as in one of the specifications in Farrell and Katz 2000). The literature (e.g. Foros 2004, pp. 4, 9, 10), commonly describes those kind of markets, as “upstream market”(Foros 2004, p. 10), i.e. market A, and “downstream market”(Foros 2004, p. 4), i.e. market S.

To describe the firms, their profit functions and the decisions they face, we stay close to the literature and the already mentioned models. Besides firms’ decisions over prices p_i $(i = A, S)$, we consider as a large body of the literature does that firms decide over investment, using a typical form (e.g., Foros 2004, p. 9, Kotakorpi 2006, p. 1014, Vareda 2007, p. 7) to increase the quality q_i of their good or service, which requires in our setup

[8] See in particular, Foros (2004) and Vareda (2007) first describing the general market and then similarly distinguishing clearly between the modeling of the consumer and firms side. However, they discuss first the consumer and then the firms, which we do the other way round. Moreover, the timing is discussed in our model similar to Vareda (2007) in the final part of the modeling strategy, while Foros (2004) does that before firms and consumers.

[9] Of course, the question may arise why a regulator would only regulate one monopoly but not both. We do not want to speculate about the reasons but simply observe that this is not uncommon in reality. For example, airport landing fees are often regulated while air ticket prices are usually not, even though some airlines virtually have a monopoly over some routes. Similarly, in most European countries, rail track access prices are regulated, while train services are not, even though there is often virtually no competition in passenger train services. The same holds for docking fees (sometimes regulated) and harbor pilotage (often monopolized, but not price regulated). Finally, broadband access may be subject to regulation while this is unlikely to happen for Internet services such as eBay, google or youtube, even though they may be almost monopolies in their market segments.

similar to Foros (2004, p. 7) that there is a minimum quality, which defines the product. Investment costs are given similar to Farrell and Katz (2000, p. 420), Foros (2004, p. 9), Kotakorpi (2006, p. 1014) Vareda (2007, p. 7) by $\frac{1}{2}k_i q_i^2$, which requires that $k_i \geq 1/2$ (assumption 1) ensuring positive investment levels (the others authors notation however, partially differs slightly; the specific necessity of assumption (1) derives from equation 4.8, however, the general necessity of investment costs being high enough is for instance also discussed in Foros 2004, p. 15). For marginal costs, we simplify the model assuming "zero marginal costs"(Vives 2001, p. 166), as it is widely done in the literature (see, for instance, for examples of this assumption, Vives 2001, pp. 133, 153, 166, Farrell and Katz 2000, pp. 416-417). This leads to the firms' profit functions:

$$\pi_i = p_i x_i - \frac{1}{2}k_i q_i^2, \tag{4.1}$$

for $i = A$, S.

To construct the consumers demand we assume that similar to the model in Farrell and Katz (2000, p. 417) consumer have desire "for a system that combines"(Farrell and Katz 2000, p. 417) both services (A and S), i.e. harbor pilotage, flight service, train service together with network access, landing fees or docking fees. For the consumers' demand we use a representative consumer model similar used in Vareda (2007, p. 6) which gives:[10]

$$x_S = a_S + q_S + \gamma q_A - p_S - p_A, \tag{4.2}$$

As it is typical in this model (e.g., Vareda 2007, p. 6), the factor $a_S > 0$ indicates, in our case of the jointly consumed services, how much a consumer valuates the consumption of the service given the minimum quality levels of market S and A. Given the proposed investment functions, we assume that investment in either A or S increases demand as also Foros (2004, p. 9), Kotakorpi (2006, p. 1014), Vareda (2007, p. 7) and similarly Farrell and Katz (2000, p. 417) do (however, these authors allow investment only into one market that corresponds to our market A).[11] Therefore, the variables q_S and q_A describe "quality-upgrades"(Vareda 2007, p. 7), which is, for instance, similarly implemented in the models of Foros (2004, p. 9), Kotakorpi (2006, p. 1014) and Vareda (2007, p. 7). Any

[10](1924), which is, for instance, also used by Singh and Vives (1984) or Vareda (2007). We use the model and change slightly to fit our case: $U = (a_S + q_S + \gamma q_A)x_S - (p_A + p_S)x_S - \frac{1}{2}x_S^2$. See also the detailed description in Vives (2001, pp. 144-148). The model used is mostly related to Vareda (2007, p. 6) who uses it in a similar environment. Consider that due to our complementarity specification the demand in both markets is equal and determined by the demand for services.

[11]See, that as also Vareda (2007, p. 8) mentions, all three authors (Foros 2004, Kotakorpi 2006, Vareda 2007) use the same quality functions, however, Foros (2004, p. 8) and Kotakorpi (2006, p. 1014) use some efficiency parameter in the provision of those ugrades.

different consumer valuation of the two components' quality is measured by $\gamma \geq 0$, which reflects the relative importance of network quality compared to service quality in the eyes of consumers and is similar, but different, to the efficiency parameters in the demand functions for the quality increase in Foros (2004, p. 8) and to the factors mentioned in Kotakorpi (2006, p. 1014). The way how we implement this factor distinguishes this to their models. A lower γ indicates less importance of network quality compared to the services' quality and vice versa. Clearly, as in all models, the prices p_S and p_A are negative in demand.

The outcome is determined in a typical two stage setup (see, similarly Foros 2004, Kotakorpi 2006, Vareda 2007): In the first stage, the two firms choose their quality simultaneously [12], before either one or both firms set their price(s).[13] The solution of this game is, as required by the literature, "working backward in time"(Farrell and Katz 2000, p. 417). We compare, as it is typical in the literature analyzing the impact of a regulator on investment incentives, two situations (see, similarly, Foros 2004, Kotakorpi 2006, Vareda 2007): A completely unregulated market (U) and a regulated network or access market (R). Without regulation, all prices are determined endogenously, while under network regulation, p_A is given exogenously (See, similar the regulatory setup of the models by Foros 2004, p. 6, Kotakorpi 2006, pp. 1015, 1017, Vareda 2007, p. 8, however, they consider regulation for a necessary input and not price regulation of a firm). We assume, knowing that the literature debates this assumption, that, under regulation, the regulator sets a price p_A^R before firms choose their quality.[14] This assumption appears to be natural, as in many countries and most regulated industries, the cost standard on which prices have to be based (such as long-run incremental cost) is enshrined in law. We also determine the welfare maximizing access price ($p_A^{R^*}$) that a welfare maximizing regulator would choose, but we concentrate on a comparative static analysis of exogenous access price variations in p_A^R, as we consider this comparison to be more relevant. In reality, regulators are (a) unlikely to pursue the

[12]This is different to the literature, which considers mostly only investment into one of those markets, e.g., Foros 2004, Kotakorpi 2006, Vareda 2007

[13]The games of the other authors are similarly, however not identically. For instance, Vareda (2007) considers the decision of entry and Foros (2004) implements a regulator between our two stages. We however, also consider a regulator, however take his decision as exogenous. Therefore, our model could also be translated in a three stage game in the regulatory case.

[14]Foros (2004, p. 6) differently assumes no commitment, by the regulator as also Kotakorpi (2006, p. 1017) does, while Vareda (2007, pp. 7-8) considers also the case of commitment by the regulator such that the latter considers a different timing while the first is considering investment before the regulators decision.

objective of welfare maximization and (b) even if they were, regulators usually lack the information and/or power to implement first-best prices.[15]

4.2.1.2 No Regulation (U)

The case, for no regulation is solved by simple optimization giving the values for $p_i(q_A, q_S)$ in equation 4.3 ($i, j = A, S$):

$$p_i(q_A, q_S) = \frac{1}{3}(a_S + q_S + \gamma q_A). \tag{4.3}$$

Given the equilibria of equation 4.3,[16] which are now used in the further optimization that provide the quality increases of the firms:

$$q_A = \gamma \frac{2k_S a_S}{\varsigma} \tag{4.4}$$

$$q_S = \frac{2k_A a_S}{\varsigma} \tag{4.5}$$

With $\varsigma = 9k_A k_S - 2k_A - 2\gamma^2 k_S > 0$

Assumption 2: We assume that $(k_A + \gamma^2 k_S)/(k_A k_S) < 9/2$ holds so that quality increases are non-negative.

4.2.1.3 Network Access Regulation (R)

Under regulation we assume that p_A^R is, as already discussed, exogenously set, without considering further optimization.[17] Therefore, only firm S optimizes its benefits to get $p_S(q_A,\ q_S,\ p_A^R)$:

$$p_S(q_A,\ q_S,\ p_A^R) = \frac{1}{2}(a_S + q_S + \gamma q_A - p_A^R) \tag{4.6}$$

[15] In our view, the assumption of a welfare maximizing regulator makes little sense. It may as well be assumed that the firm is publicly owned and sets welfare maximizing prices. From reality, we know that this assumption is usually not fulfilled and does not yield useful predictions.

[16] All second order conditions in this chapter have been calculated and are valid, taking into account all assumptions given.

[17] For completeness, an endogenous, welfare maximizing access price is provided in the appendix.

Taking the previous step into account in the firms' decisions, firm A and firm S qualities are then:

$$q_A(\ p_A^R) = \frac{\gamma}{2k_A} p_A^R \tag{4.7}$$

and

$$q_S(\ p_A^R) = \frac{1}{2k_S - 1} \left(\underbrace{(a_S - p_A^R)}_{\text{direct effect}} + \underbrace{\frac{\gamma^2}{2k_A} p_A^R}_{\text{indirect effect}} \right) \tag{4.8}$$

As can be easily seen, and has been similarly shown in the mentioned access price regulation models (e.g., however for the impact of access pricing on quality, Foros 2004, Kotakorpi 2006, Vareda 2007) q_A is increasing in p_A^R. The strength of the effect depends on (a) how many consumers value network quality (as expressed by γ) and (b), which is not surprisingly, how costly the improvement of network quality is (as measured by k_A). As it is naturally, cheaper quality investments lead to more investments, which increase consumers' demand such that the impact of access price (de)regulation on network quality q_A will be stronger.

How a change in p_A^R affects q_s is less obvious, as the sign of the derivative of $\partial q_s / \partial p_A^R$ can be either positive or negative. As it is also similarly done in the literature (e.g., Vareda 2007, pp. 14-15), we can distinguish between a *direct* effect and an *indirect* effect. In our case there is on the one hand, there is a *direct* effect, which is negative: An increase in p_A^R (which may be called "deregulation") reduces the demand for complementary services, x_S, which in turn reduces the incentives to invest into the quality of complementary services.[18] This effect can easily identified in our demand equation(4.2), showing that an increase in p_A^R reduces valuation for complementary services by a factor of 1. On the other hand, there is a countervailing *indirect* effect: An increase in p_A^R also leads to an increase in network quality by a factor of $\gamma/(2k_A)$, as can be seen from equation (4.7). Any increase in network quality in turn also increases the demand for x_S by a factor of γ as the demand equation (4.2) reveals, so that the *indirect* effect of an increase in p_A^R is to raise consumers' demand by a factor of $\gamma^2/(2k_A)$, due to the resulting increase in q_A. Therefore, the total effect that a change in p_A^R has on q_s depends on the size of γ and k_A. This means, the sign of the derivative $\partial q_s / \partial p_A^R$ is determined by the sign of $(\gamma^2/(2k_A) - 1)$. If network quality is sufficiently important for consumers (as measured through γ) and/or if network investments are sufficiently inexpensive (as measured through k_A), access price deregulation (a higher p_A^R) leads not only to higher network quality, q_A, but also to a

[18]See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects, however they are defined slightly different.

higher quality of related services, q_S. This finding is summarized in the following two propositions[19]:

Proposition 1. *Access price deregulation (i.e., a higher p_A^R) unambiguously leads to higher network quality and also to higher quality of related services if $\gamma^2/(2k_A)$ is sufficiently large.*

Proposition 2. *If the regulator strengthens price regulation for network access (i.e., a lower p_A^R), network quality will decrease, but the quality level in the unregulated market for complementary services increases if $\gamma^2/(2k_A)$ is sufficiently small.*

Given the second proposition, the question almost automatically arises how total quality is affected overall. Or differently, how overall perceived quality, i.e. total quality, is affected. We ask how consumers' demand for x_S is affected. This means, we define total quality as:

$$Q_{Total} = \gamma q_A + q_S \tag{4.9}$$

Total quality is defined as the sum of network and service quality as given by equations (4.7) and (4.8), corrected for the consumers' valuation γ of network quality. The derivative of the so-defined total quality, Q, with respect to p_A^R is:

$$\frac{\partial Q}{\partial p_A^R} = \frac{1}{2k_S - 1}\left(\underbrace{\frac{k_S}{k_A}\gamma^2}_{\text{indirect effect}} \underbrace{-1}_{\text{direct effect}}\right) \gtreqless 0 \tag{4.10}$$

The sign of equation (4.10) depends on the strength of the two effects mentioned above (direct and indirect effect) if $k_S > \frac{1}{2}$(assumption 1).[20] The direct effect has the factor -1 and the indirect effect has the factor $\frac{k_S}{k_A}\gamma^2$. Therefore, the sign of the term $\gamma^2\frac{k_S}{k_A} - 1$ shows whether $\frac{\partial Q}{\partial p_A^R}$ is positive or negative. A relative higher importance of the regulated sector, leads to a less likely a positive impact of regulation on the total quality. Moreover, the indirect factor depends on the relationship between the investment costs in the two sectors. Higher costs for the investment in the unregulated sector, lead to a reduced likelihood of a a positive impact of regulation on total quality. The opposite is true for investment costs in the regulated sector. These results can be summarized in the following proposition.

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[19]The result of reduced investment incentives due to regulation is in line with the common findings of the literature for instance in Foros (2004) or Kotakorpi (2006).

[20]The specific necessity of this assumption derives from the specific quality functions, however, the general necessity of investment costs being high enough is for instance also discussed in Foros (2004, p. 15). See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

Proposition 3. *If the regulator strengthens price regulation for network access (i.e., a lower p_A^R), network quality will decrease, but the quality level in the unregulated market for complementary services increases if $\gamma^2 \frac{k_S}{k_A}$ is sufficiently small and overcompensates the loss such that total quality increases.*

4.2.1.4 Quality with and without Network Access Regulation

The comparative static analysis above shows how in an access regulation environment, intensity of regulation changes investment incentives. Now we compare the outcomes of the regulated and the unregulated environment. Equation (4.11) shows the difference regarding investment in the potentially regulated sector. The provided quality is always higher in the unregulated setup. However, the difference to the regulated setup decreases if the price is deregulated.

$$q_A - q_A(p_A^R) = \gamma \frac{(4a_S k_A k_S) - p_A^R \varsigma}{k_A \varsigma} > 0 \tag{4.11}$$

Equation (4.12) shows that the quality in the unregulated sector may either be higher or lower in the regulated setup. In general, the same effects apply as in the previous subsection. If $\frac{\gamma^2}{2k_A}$ is relatively low, a lower p_A^R leads to a higher probability that $q_S(p_A^R)$ is higher than q_S. The exact size of the difference, however, depends on the value for each factor.[21]

$$q_S - q_S(p_A^R) = \frac{2k_A a_S(2k_S - 1) - \left(a_S + (\frac{\gamma^2}{2k_A} - 1)p_A^R\right)\varsigma}{\varsigma(2k_S - 1)} \gtrless 0 \tag{4.12}$$

The same is true for the outcome of the total quality. Depending on the relative strength of the direct and indirect effect, total quality can either be positively or negatively affected by access price regulation.[22] The same general effects as in the previous subsection occur.[23]

$$Q_{Total} - Q_{Total}^R = (\gamma q_A + q_S) - (\gamma q_A(p_A^R) + q_S(p_A^R)) \gtrless 0 \tag{4.13}$$

[21]Due to complexity, the solution cannot be derived analytically, but only numerically. Calculations show that constellations either for a higher or lower total quality outcome are possible. A graphical example for either case is given in the appendix.

[22]See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

[23]As above, solutions can only be derived numerically, a graphical example for either case is given in the appendix.

4.2.2 Upstream Monopoly & Downstream Duopoly

4.2.2.1 Model Setup

Now we change the model and introduce competition in the downstream market S with the firms $S1$ and $S2$ such that the model becomes even more similar to the models of Foros (2004), Kotakorpi (2006) and Vareda (2007). However, it still has the clear separation between the access and service sector firms and has a specific, different, consumer utility function. In particular, in contrast to Foros (2004)[24] and analogous to Vareda (2007) the firms' competition takes place via their decision regarding prices. The demand uses a representative consumer model that is for instance also used similarly by Vareda (2007), however, we change it slightly to fit our framework.[25,26]

As in the previous section, we compare the same two regulatory situations, without any change in the timing. However, due to the change in market structure, the demand for the firms in sector S is[27] which is $p_{S_{i,j}} = a_S - x_{S_{i,j}} - p_A + q_{S_{i,j}} - bx_{S_{j,i}} + \gamma q_A$ with $i, j = 1, 2$.

4.2.2.2 No Regulation (U)

The game is solved in the same way as in the previous section, with:

$$p_A(q_A, q_{S1}, q_{S2}) = \frac{\Lambda}{(3-b)} \tag{4.14}$$

$$p_{Si}(q_A, q_{Si}, q_{Sj}) = \frac{\Lambda(1-b)}{(3-b)} \tag{4.15}$$

$$i, j = 1, 2$$

With $\Lambda = a_S + q_{S_{i,j}} + \gamma q_A$

[24] Foros (2004) considers differently to us, competition in quantities.

[25] We consider for different intensities of competition between the two firms implemented due to flexible degrees of substitutability (similarly, Vareda 2007, p. 6) in the demand function (see, for a description of the representative consumer model and its substitutability interpretations, Vives 2001, pp. 144-148)

[26] One may think that the whole mechanism is only working due to a double mark-up problem. Introduction of competition in the S sector helps to tackle that argument, because now, combinations are possible in which the sum of all prices paid by the customer are below the price of an integrated monopolist. As long as all conditions derived hold for the whole spectrum of possible prices, the driver for the results cannot be exclusively the double mark-up problem.

[27] Demand is derived by the standard representative consumer utility function, which we slightly change for our needs (See, for the description of the general model, e.g. Vives 2001, pp. 144-148; See also Vareda 2007, p. 6, using this model in a similar problem): $U = (a_S + q_{S1} + \gamma q_A)x_{S1} + (a_S + q_{S2} + \gamma q_A)x_{S2} - (p_A + p_{S1})(x_{S1}) + (x_{S2})(p_A + p_{S2}) - \frac{1}{2}(x_{S1}^2 + 2bx_{S1}x_{S2} + x_{S2}^2)$

and analogous to the previous subsections' optimization q_A and $q_{Si,j}$:

$$\begin{aligned} q_A &= \frac{4a_S(2+b)k_S\gamma}{\Phi} \quad (4.16) \\ q_{Si,j} &= \frac{a_S(5+b(1-2b))k_A}{\Phi} \quad (4.17) \\ & i,j=1,2 \end{aligned}$$

With $\Phi = k_A\left(2b^2+(3-b)^2(1+b)(2+b)k_S-5-b\right)-4(2+b)k_S\gamma^2>0$

4.2.2.3 Network Access Regulation (R)

Still the same procedure as in the previous section applies. However, we have to consider that the downstream firms compete in $p_{Si,Sj}$, while the firm A just takes p_A:

$$p_{Si,j}(\ q_A, q_{Si}, q_{Sj}, p_A^R) = \frac{\Lambda^{WIP}(2-b(1+b))}{4-b^2} \quad (4.18)$$

$$i,j=1,2$$

with $\Lambda^{WIP} = a_S + q_{S1} + \gamma q_A - p_A^R$

Taking this into account and assuming that due to equality in marginal costs and investment costs, the firms derive their optimal q_A or q_{Si} (i,j=1,2) :

$$\begin{aligned} q_A(\ p_A^R) &= \frac{2}{(2-b)(1+b)}\frac{\gamma}{k_A}p_A^R \quad (4.19) \\ q_{Si}(q_A, q_{Sj}, p_A^R) &= \frac{2(2-b^2)(a_S-p_A^R+\gamma q_A)}{(8k_S-4)+2b^2+bk_S(4-6b-b^2+b^3)} \quad (4.20) \\ & i,j=1,2 \end{aligned}$$

Evidently as equation 4.20 shows, in the same way as in the previous section, changes of p_A^R effect q_{S1} and q_{S2} by an direct $\frac{\partial q_S}{\partial p_A}$and indirect effect $\frac{\partial q_S}{\partial q_A}\frac{\partial q_A}{\partial p_A}$.[28] Solution of the reaction functions provides the resulting quality in dependence of the regulated price p_A^R:

$$q_A(p_A^R) = \frac{2}{(2-b)(1+b)}\frac{\gamma}{k_A}p_A^R \quad (4.21)$$

[28]See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

$$q_{Si,j}(\,p_A^R) = \frac{2}{\lambda}\left(\underbrace{a_S - p_A^R}_{\text{direct effect}} + \underbrace{\frac{2\gamma^2}{k_A(2-b)(1+b)}p_A^R}_{\text{indirect effect}}\right)(2-b^2) \tag{4.22}$$

$$i,j = 1,2$$

With $\lambda = \left(8k_S + 4bk_S + 2b^2 - 6b^2k_S - b^3k_S + b^4k_S - 4\right) > 0$

The effect price regulation has on investment incentive is analogous to what we have found in the previous specification, i.e. for market A negative (equation 4.21), which is still the same as other authors find for access price regulation (e.g., however for the impact of access pricing on quality, Foros 2004, Kotakorpi 2006, Vareda 2007).

Investment in the service sector still show the same general results, as in the setup with two monopolies. This is shown in equation 4.22. First, it is important to consider that the assumption, discussed above, $k_S > \frac{1}{2}$, still ensures that the denominator is positive for the relevant values.[29] The sign of the nominator, therefore, determines the sign of the derivation $\frac{\partial}{\partial p_A^R}q_{S1}$. The derivation shows, as in the previous specification, that the two effects mentioned (direct and indirect effects) have different signs.[30] As before the direct effect is negative (-1) while the indirect effect is positive $\frac{2\gamma^2}{k_A(b-b^2+2)}$. Still, the importance for the consumer for the access good as well as the investment costs are crucial factors. This can be summarized in the following propositions that are analogous to the previous sections' findings [31]:

Proposition 4. *Access price deregulation (i.e., a higher p_A^R) unambiguously leads to higher network quality and also to higher quality of related services if $\frac{2\gamma^2}{k_A(b-b^2+2)}$ is sufficiently large.*

Proposition 5. *If the regulator strengthens price regulation for network access (i.e., a lower p_A^R), network quality will decrease, but the quality level in the unregulated market for complementary services increases if $\frac{2\gamma^2}{k_A(b-b^2+2)}$ is sufficiently small.*

[29]The specific necessity of this assumption derives from the specific quality functions, however, the general necessity of investment costs being high enough is for instance also discussed in Foros (2004, p. 15).

[30]See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

[31]As already discussed above, the first result is in line with the common findings of the literature.

Analogous to the previous setup we investigate the total quality given by: $Q_{Total} = \gamma q_A + \frac{1}{2} q_{S1} + \frac{1}{2} q_{S2}$.[32] The sign of the derivation is determined by the sign of $\frac{\gamma^2(4-b^2)^2}{k_A(8-6b^2+b^4)} - 1$. Also here, we find that a high importance of the valuation for the access good reduces the probability that less strength regulation has a positive impact on the overall quality perceived, or in other words, total quality. Regarding the impact competition has, it is straightforward to see that $\frac{\partial \frac{\gamma^2(4-b^2)^2}{k_A(8-6b^2+b^4)}}{\partial b} > 0$. This indicates that the level of competition, reduces the possibilities that tougher regulation has a positive impact total quality.

Proposition 6. *If the regulator strengthens price regulation for network access (i.e., a lower p_A^R), network quality will decrease, but the quality level in the unregulated market for complementary services increases and overcompensates the loss if $\frac{\gamma^2(4-b^2)^2}{k_A(8-6b^2+b^4)}$ is sufficiently small such that total quality increases.*

Proposition 7. *The likelihood for a positive impact of regulation on the total provision is negatively related to downstream competition.*

4.2.2.4 Quality with and without Network Access Regulation

As in the previous section, comparison of the outcomes in an regulated and not regulated environment are analyzed. The potentially regulated setup provides a higher quality outcome without regulation (4.23), however, the difference is decreasing in the regulated price.

$$q_A - q_A(p_A^R) = \frac{4a_S(2+b)k_S\gamma}{\Phi} - \frac{2}{(2-b)(1+b)}\frac{\gamma}{k_A}p_A^R > 0 \tag{4.23}$$

Quality in the unregulated sector (4.24) can, can also be here, either be higher or lower if regulation takes place. As in the previous case, the probability that the regulated setup yields a higher outcome in quality than the unregulated setup depends on the size, of the previously identified, direct and indirect effect.[33] The exact size of the difference depends on the size of all factors.[34]

$$q_S - q_S(p_A^R) = \frac{a_S(5+b(1-2b))k_A}{\Phi} - \frac{2}{\lambda}\left(a_S - p_A^R + \frac{2\gamma^2}{k_A(2+b-b^2)}p_A^R\right)(2-b^2) \gtrless 0 \tag{4.24}$$

[32]This assumes that downstream companies are equal in term of costs and resulting demand expression.

[33]See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

[34]As in the previous section, these results can only be derived numerically. Graphical examples are provided in the appendix.

The same is true for the outcome of the total quality, which can be either higher or lower in a regulated or not regulated framework.[35]

$$Q_{Total} - Q_{Total}^{R} = (\gamma q_A + q_S) - (\gamma q_A(p_A^R) + q_S(p_A^R)) \gtrless 0 \tag{4.25}$$

4.3 Extension: Investment Incentives with Partial Complementarity

This section relaxes the assumptions of the "strictly complementary components"(Farrell and Katz 2000, p. 413) to apply the underlying mechanism to a larger group of goods and services. It uses only a basic setup to show that derived results are consistent with changes in the level of complementarity. Market intervention does not necessarily take place through a regulating authority, but can be carried out by an antitrust authority that lowers the price of a product and therefore works in the same way as price regulation in the previous section. We proceed to call this market intervention regulation to avoid confusion. The rest of the section follows the same structure as the previous one. First, the adjustments of the model setup are described. Then the analysis of the different scenarios follows. Finally, results regarding quality outcome are analyzed.

4.3.1 Model Setup

In this setup we follow the market structure of the first specifications with two firms. Examples can be price searching website and online stores. We assume that both have a complementary effect on each other that takes place in the complementarity factor s.[36] Moreover, the quality of one market depends on the quality of the other market. To stay with our example, the quality of the price searching website depends on the quality provided by the online store. It is possible that quality improvements makes it easier or more comfortable to buy goods (maybe due to special interfaces connecting the price searching website with the online store) such that this enhances the perceived quality of the consumer.

[35] As above, solutions can only be derived numerically.

[36] This complementarity factor is essentially the factor describing either differentiation or complementarity within the standard representative consumer model described in detail by Vives (2001, p. 145).

We do not change the assumptions, discussed in the previous model regarding firms' pricing and their marginal costs. What we change is consumers utility function.[37] Still, we have a complementary relationship, but this is captured in the typical factor of the model $s \in (0, \sqrt{\frac{2k_S-1}{2k_S}})$, which indicates, because it is positive that products are complements (see, for a description of the conditions of complementarity in this standard model Vives 2001, p. 145).[38] Moreover, the quality in one market affects the quality in the other market. Quality of one market has an impact on the other due to factor γ, which is similar to the previous setups our models unique point. The factor γ can also here be seen as a relative indicator for importance regarding the quality in the S sector. Considering these assumptions, gives:

$$x_A = a_A + q_A - p_A + sx_S \tag{4.26}$$

$$x_S = a_S + q_S - p_S + \gamma q_A + sx_A \tag{4.27}$$

As one can see this demand is similar, to the previous sections' demand functions, however, now with a basic utility for both goods separately captured in a_i (see, analogous in, Vareda 2007, p. 7) as well as a utility in the quality increase in each market q_i (See, as in the previous section the quality investment specification in Foros 2004, Kotakorpi 2006 and Vareda 2007).[39] It can easily be seen, as the standard model (Vives 2001, pp. 145-146) suggest that both markets' demand is increasing in the other markets' quantity in the intensity of the complementarity factor s. Moreover, the quality of market A has an impact on the market S in the intensity of the quality factor γ. This indicates that quality in market A partially determines quality in market S. The market A will be subject to regulation as in the previous setup.

As in the previous setup, the outcome is determined in the same two stages (see, similarly, Foros 2004, Kotakorpi 2006, Vareda 2007).[40] We analyze the same two variations (No Regulation and Regulation) as in the previous setups and the mentioned literature (similarly, Foros 2004, Kotakorpi 2006, Vareda 2007).

[37]Utility is derived by the popular representative consumer model according to Bowely (1924), which is, for instance, also used by Singh and Vives (1984) or Vareda (2007). We use the model and change slightly to fit our case. $U = (a_A + q_A)x_A + (a_S + q_S + \gamma q_A)x_S - \frac{1}{2}(x_A^2 - 2sx_Sx_A + x_S^2) - p_Ax_A - p_Sx_S$. See also the detailed description in Vives (2001, pp. 144 -148).

[38]The specific necessity of this assumption derives from later investment optimizations and is related to size of minimum size of investment costs, which is a typical requirement that in general has also been discussed for instance also discussed in Foros 2004, p. 15.

[39]To ensure that there are no negative or unlimited values of investment, we assume $k_S \geq \frac{1}{2(1-s^2)}$ (the specific necessity of this assumption derives from later investment optimizations, however, the general necessity of investment costs being high enough is for instance also discussed in Foros 2004, p. 15).

[40]See that the mentioned models do have similar, stages, but not the same, as discussed above.

4.3.2 No Regulation (U)

The outcome without regulation is determined in the same way as in the previous section. Therefore, we get $p_A(q_A, q_S)$ and $p_S(q_A, q_S)$:

$$p_A(q_A, q_S) = \frac{(2 - s^2)(a_A + q_A) + s(a_S + q_S + \gamma q_A)}{4 - s^2} \tag{4.28}$$

$$p_S(q_A, q_S) = \frac{(2 - s^2)(a_S + q_S + \gamma q_A) + s(a_A + q_A)}{4 - s^2} \tag{4.29}$$

Analogous to the previous model setup, we use these results to derive q_A and q_S:

$$q_A = \frac{2(a_S s \varrho_S - a_A \psi(2 + \varrho_S))\chi}{\varrho_A(2\psi^2 + \varrho_S(\psi - 2)(\psi + 1)) + 2\chi(2\psi + \varrho_S \chi))} \tag{4.30}$$

$$q_S = \frac{2\psi(2a_S s\gamma - a_S\psi(2 + \varrho_A) - a_A(-s\varrho_A + 2\gamma(2 + s(-s + \gamma)))}{\varrho_A(2\psi^2 + \varrho_S(\psi - 2)(\psi + 1)) + 2\chi(2\psi + \varrho_S \chi))} \tag{4.31}$$

with: $\chi = \left(s^2 - 2 - s\gamma\right)$, $\psi = (s^2 - 2)$, $\varrho_A = k_A\left(s^2 - 4\right)$,$\varrho_S = k_S\left(s^2 - 4\right)$.

4.3.3 Network Access Regulation (R)

The solution of the games follows the same procedure and the same two stages as in the previous section. In the third stage, firm S derives $p_S(q_A, q_S, p_A^R)$, while p_A is set:

$$p_S(q_A, q_S, p_A^R) = \frac{1}{2}\left(a_S + q_S + \gamma q_A + s(a_A + q_A - p_A^R)\right) \tag{4.32}$$

The equation shows that prices set by firm S depend twofold on the behavior of the other firm. First, due to the quality factor γ, quality q_A effects the possible price set and secondly, due to the complementarity factor s, has an impact on the valuation for the goods $a_A + q_A - p_A^R$. The demand in good S is, therefore, affected due to the complementarity factor and the quality effect of market A.

Clearly, these result given in 4.32 lead to $q_A(p_A^R)$ and to $q_S(p_A^R)$:

$$q_A(p_A^R) = \frac{\left(2 + s\gamma - s^2\right)}{2k_A(1-s^2)} p_A^R \tag{4.33}$$

$$q_S(p_A^R) = \frac{1}{\Delta}\left(a_S + s\left(a_A - p_A\right) + \frac{1}{2k_A} p_A \frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)\right) \tag{4.34}$$

Assumption: To ensure that investments in market S are non-negative, Δ *must be larger than 0 such that s should not exceed too large of a value such that* $s < \sqrt{\frac{2k_S - 1}{2k_S}}$.

Both quality levels now, similar to the previous setups, depend on the level of the regulated price p_A^R. To investigate the impact of price regulation on each quality level, we differentiate between quality provided in market A (equation 4.33) and quality provided in market S (equation 4.34). First, we check $\partial q_A \partial p_A^R$:

$$\frac{\partial q_A}{\partial p_A^R} = \frac{\left(2 + s\gamma - s^2\right)}{2k_A(1-s^2)} > 0 \tag{4.35}$$

Taking into account the variable definitions, the numerator and denominator of the derivation shown are negative for the relevant values. The overall term is therefore positive. This implies that a price decrease forced by regulation leads, as seen in the other setups, to a decrease in market A's quality. This however is not surprising. To analyze the relationship in the second market, we derive q_S given in equation (4.34) to p_A^R.

$$\frac{\partial q_S}{\partial p_A^R} = \frac{1}{\Delta}\left(\underbrace{-s}_{\text{direct effect}} + \underbrace{\frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)}_{\text{indirect effect}}\right) \gtrless 0 \tag{4.36}$$

The derivation indicates that regulation can have, in line with the previous findings, a negative as well as a positive impact on the quality provision in the unregulated market S. As before a similar direct ($-s$) and indirect ($\frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)$) effect can be identified.[41] In particular, the indirect effect should not be too large and the direct effect, which one can call the complementarity factor, should be large enough. In particular, high γ and low investment costs k_A increase the probability that the indirect is larger then the

[41] See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

direct effect. These findings confirm the previous specifications' results and indicate that effects hold for a variety of complementarity specifications.

Proposition 8. *Access price deregulation (i.e., a higher p_A^R) leads to higher network quality and also to higher quality in the partial complementary market for related services if $\frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)$ is sufficiently small and the complementarity factor is sufficiently high.*

Proposition 9. *If the regulator strengthens price regulation for network access (i.e., a lower p_A^R), network quality will decrease, but the quality level in the partial complementary market for related services increases if $\frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)$ is sufficiently large and the complementarity factor is sufficiently small.*

To analyze the impact of regulation on overall, total quality, we use also here as before the perceived quality, which is quality in market A, multiplied by its influence in the demand functions and quality in market S:

$$Q_{Total} = (1+\gamma)q_A + q_S \tag{4.37}$$

The impact of price regulation now can be determined by derivation of the total quality regarding p_A.

$$\frac{\partial}{\partial p_A^R} Q_{Total} = \underbrace{(1+\gamma)(\frac{\left(2+s\gamma-s^2\right)}{2k_A(1-s^2)})}_{\substack{\text{market A} \\ >0}} + \underbrace{\frac{1}{\Delta}\left(-s + \frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)\right)}_{\substack{\text{market S} \\ \gtrless 0}} \lesseqgtr 0 \tag{4.38}$$

The effect of price regulation on total quality can, also in this specification, be either positive or negative. It still depends first on the effect price regulation has on market S. If a tighter regulation spurs investment in market S, that is if the derivation is negative, it may be that this outweights the negative effect tighter regulation has on the market A. If, however, the effect of tighter regulation leads to less investment in market S, the overall effect of regulation on investment is strictly negative. This is essentially the same finding as in the previous specification, however, with different assumptions.

Proposition 10. *If the regulator strengthens price regulation for network access (i.e., a higher p_A^R), the regulated markets quality will decrease, but the quality level in the unregulated market for partial complementary services increases and overcompensates the loss if the impact on market S $\frac{1}{\Delta}\left(-s + \frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma - s^2 + 2\right)\right)$ is sufficiently negative and $(1+\gamma)(\frac{\left(2+s\gamma-s^2\right)}{2k_A(1-s^2)})$ is sufficiently small.*

Proposition 11. *If the regulator strengthens price regulation for network access (i.e., a lower p_A^R), the regulated markets quality will decrease, and the quality level in the unregulated market for partial complementary services will always decrease if the impact on market S given by $\frac{1}{\Delta}\left(-s+\frac{1}{2k_A}\frac{s+\gamma}{1-s^2}\left(s\gamma-s^2+2\right)\right)$ is not negative*

4.3.3.1 Quality with and without Network Access Regulation

As in the previous section, a comparison of the outcomes in an regulated and in an unregulated environment are analyzed. The potentially regulated setup provides still a higher quality outcome without regulation (4.39), however, in line with the above literature and previous findings, the difference is decreasing in the regulated price.

$$q_A - q_A(p_A^R) > 0 \tag{4.39}$$

Quality in the unregulated sector (4.40) can also here be either higher or lower if regulation takes place. This depends also in this specification on the size of the direct and indirect effect as well as of the specific constellation of investment costs, basic utilty, the quality importance factor and the complementarity factor s.[42]

$$q_S - q_S(p_A^R) \gtrless 0 \tag{4.40}$$

The same is true for the outcome of the total quality.[43]

$$Q_{Total} - Q_{Total}^R = ((1+\gamma)q_A + q_S) - ((1+\gamma)q_A(p_A^R) + q_S(p_A^R)) \gtrless 0 \tag{4.41}$$

4.4 Conclusions

Our chapter contributes to the existing literature regarding the relationship between regulation and incentives for investments into quality. We have introduced a model to analyze the effects on complementary markets. We show that once complementary service markets are taken into account, access regulation can have a positive effect on the quality provided

[42] As above, solutions can only be derived numerically. A graphical example for either case is given in the appendix. See Vareda (2007, pp. 14-15) in his model analysis similarly distinguishing between direct and indirect effects.

[43] As above, solutions can only be derived numerically. A graphical example for either case is given in the appendix.

in an unregulated service market. If this effect is strong enough, the overall effect on perceived quality can be positive. However, in contrast to usual intuition, access regulation can also have a negative effect on quality investment in the complementary sector. Quality investment in the unregulated service market is negatively affected by access regulation if the indirect effect on the demand of this market dominates the direct effect on this market. Considering broadband Internet access, its regulation can have a positive effect on the total, overall perceived, quality of Internet service consumption, which consists of the quality of both Internet access and Internet services. This is a novel result that should be considered in regulatory decisions. Moreover, relaxing the assumptions on the complementarity, we can show that the observed effects are also relevant in a setup of partial complementarity and, therefore, in a large range of other scenarios.

Our results imply that future analysis of the effects of regulation on quality provision of regulated markets has to consider related markets, since the effects are many fold. Regulatory and antitrust authorities should take complementarity between markets into account when analyzing the effects of possible regulation or antitrust enforcement as it may lead to uncalculated effects.

4.5 Appendix

Perfect complementarity setup: Up- and downstream Monopoly

Welfare maximizing price The regulator maximizes welfare W regarding the price p_A, given that $k_S = 1$, which provides: $p_A = \frac{4a_S k_A}{\gamma^2} \frac{\gamma^2 - k_A}{5k_A - 2\gamma^2}$. To ensure that p_A is larger $\frac{\gamma^2 - k_A}{5k_A - 2\gamma^2} > 0$, the following condition must be fulfilled: $k_A < \gamma^2 < \frac{5}{2}k_A$

Assumption i : $k_A < \gamma^2 < \frac{5}{2}k_A$ As long as assumption i holds, the welfare maximizing price is non-negative.

Quality with and without Network Access Regulation

We take into account only one example to derive examples for the comparison between the regulated and not regulated setup. We assume $a_S = 10$ & $k_S = k_A = 1$. Therefore, we derive the following formula for the comparison between the regulated q_A and the not regulated $q_A(p_A^R)$

$$q_A - q_A(p_A^R) = \frac{20\gamma}{9 - 2\gamma^2} - \frac{\gamma}{2}p_A^R \tag{4.42}$$

The example illustrates that $q_A - q_A(p_A^R)$ is decreasing in price, meaning that the lower the regulated price, the larger is the difference to the unregulated setup.

$$q_S - q_S(p_A^R) = \frac{20\gamma}{7 - 2\gamma^2} - 10 - \frac{1}{2}(\gamma^2 - 2)p_A \tag{4.43}$$

The example shows that $q_S - q_S(p_A^R)$ is increasing in price as long as $\gamma < 2$. This means that the higher the regulated price, the smaller is the difference $q_S - q_S(p_A^R)$.

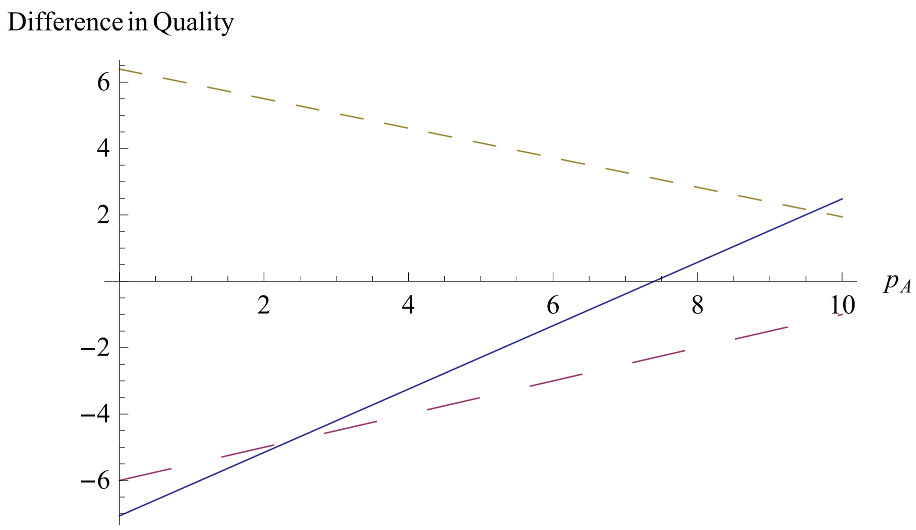
$$Q_{Total} - Q_{Total}^R = \frac{50}{7 - 2\gamma^2} - 20 - (\gamma^2 - 1)p_A \tag{4.44}$$

The example shows that $Q_{Total} - Q_{Total}^R$, depending on the constellation of γ, is either positive or negative. If γ is small enough, the outcome in the regulated setup may well be higher than in the not regulated setup, however, the opposite is possible if γ is high enough.

Perfect complementarity setup: Upstream Monopoly and downstream Duopoly

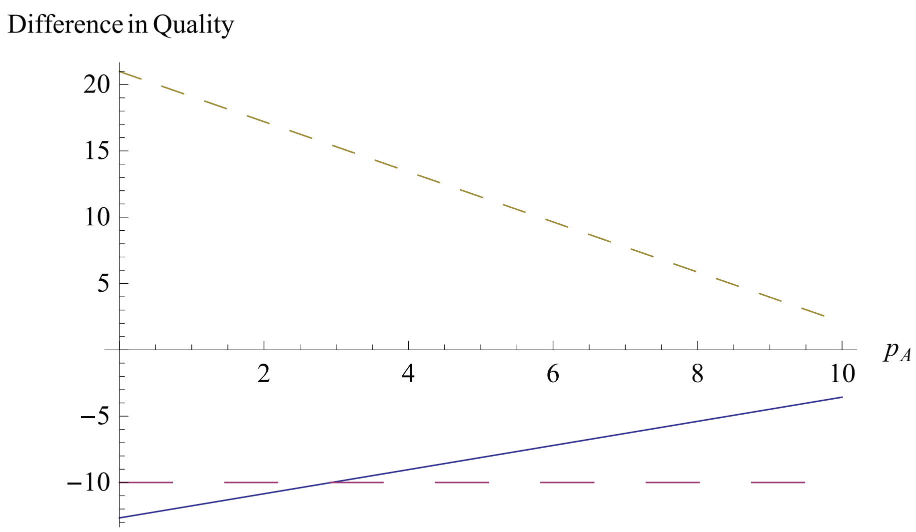
Welfare Maximizing Price

Figure 4.1: Quality in Complementary Services



Note: The lines indicate the difference between investment in complementary services $q_S - q_S(p_A^R)$ in an unregulated and a regulated setup. The narrow dashed line indicates a high γ the wide dashed a medium γ, and the bold line a low γ.

Figure 4.2: Total Quality



Note: The lines indicate the difference between investment between total quality $Q_{Total} - Q_{Total}^R$ in an unregulated and a regulated setup. The narrow dashed line indicates a high γ, the wide dashed a medium γ and the bold line a low γ.

Given that $k_{Si} = 1$, we get p_A^R:

$$p_A^R = \frac{a_S \Lambda \left(\psi k_A + 2\Lambda_3\right)}{2\left(\Lambda + 8\gamma^2\right)\left((32 + \Lambda_2)k_A + \Lambda_3\right)} \geqslant 0$$

$\psi = 128 - 28b^2 + b^4 > 0$ $\Lambda = (b-4)(2+b)k_A < 0$ $\Lambda_2 = (b-8)b(2+b) < 0$ $\Lambda_3 = 8(b-3)(4+b)\gamma^2 < 0$

Assumption ii : The welfare maximizing price is non-negative. If the welfare maximizing price formula is negative, we assume that the regulator sets $p_A = 0$. No subsidies for below cost pricing are taken into account.

Quality with and without Network Access Regulation

We assume $a_S = 10$, $k_S = k_A = 1$, $b = \frac{1}{2}$. Therefore, we have for the comparison between the regulated p_A^R and the not regulated $q_A(p_A^R)$ quality:

$$q_A - q_A(p_A^R) = \frac{320\gamma}{59 - 32\gamma^2} - \frac{8\gamma}{9} p_A^R \tag{4.45}$$

$q_A - q_A(p_A^R)$ is, in this example decreasing in price.

$$q_S - q_S(p_A^R) = \frac{160}{59 - 32\gamma^2} - \frac{56}{711}(90 + (8\gamma^2 - 9)p_A \tag{4.46}$$

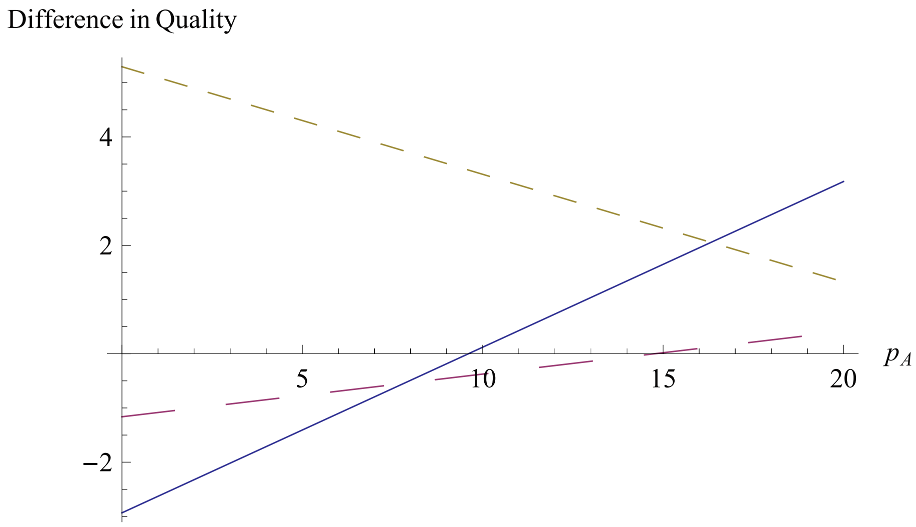
$q_S - q_S(p_A^R)$ is increasing in price as long as $\gamma^2 < \frac{9}{8}$.

$$Q_{Total} - Q_{Total}^R = \frac{8}{79}\left(\frac{150(36\gamma - 17)}{59 - 32\gamma^2} - (15\gamma^2 - 7)p_A\right) \tag{4.47}$$

The example shows that $Q_{Total} - Q_{Total}^R$, depending on the constellation of γ, is either positive or negative. If $\gamma^2 < \frac{7}{15}$ is small enough, the outcome in the regulated setup may well be higher than in the not regulated setup, however, the opposite is possible if γ is high enough.

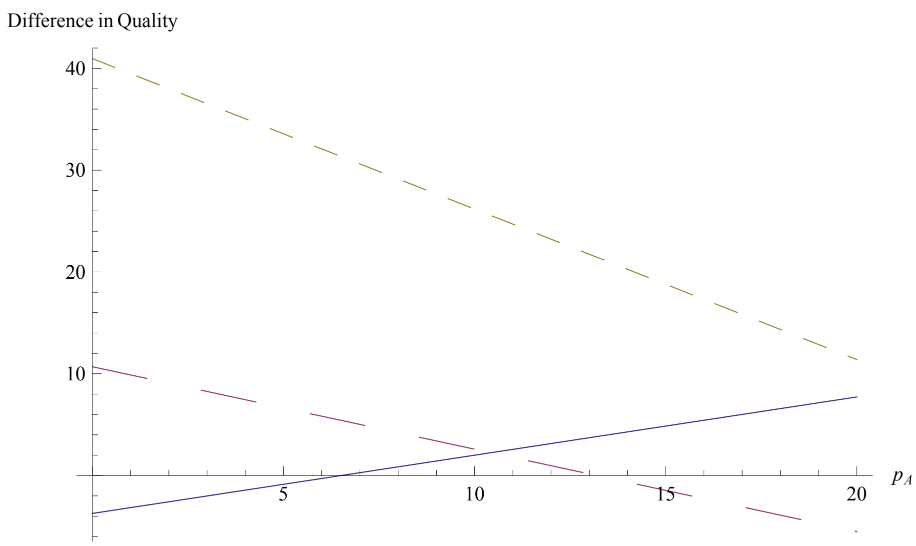
Partial complementarity setup: Up- and downstream Monopoly

Figure 4.3: Quality in Complementary Services



Note: The lines indicates the difference between quality in complementary services $q_S - q_S(p_A^R)$ in an unregulated and regulated setup. The narrow dashed line indicates a high γ, the wide dashed a medium γ and the bold line a low γ.

Figure 4.4: Total Quality



Note: The lines indicate the difference between quality in complementary services $q_S - q_S(p_A^R)$ in an unregulated and a regulated setup. The narrow dashed line indicates a high γ, the wide dashed a medium γ and the bold line a low γ.

Welfare maximizing price in the partial complementary setup: For simplification: $k_A = k_S = 1$, $a_A = a_S = 10$ and $s = 0.3$. These are, however, arbitrary but possible values. Therefore, the simplification leads to the optimized p_A :

$$p_A = \frac{78.867 - (0.438 + \gamma)(6.528 + \gamma)}{(\gamma - 0.413) * (0.82 + \gamma)(5.839 + \gamma)(7.08 + \gamma)} \geqslant 0$$

Assumption iii : $\gamma - 0.413 \geqslant 0$ such that p_A is continuous.

Quality with and without Network Access Regulation We assume $a_S = a_A = 10$ $, k_S = 4,\ k_A = 8, s = 0.02$. Therefore, we get $q_A - q_A(p_A^R)$.

$$q_A - q_A(p_A^R) = \frac{-417.18 - 65.53 - 0.02(-17.22 + \gamma)(6.37 + \gamma)(29.14 + \gamma)p_A^R}{(-17.22 + \gamma)(29.14 + \gamma)} > 0 \quad (4.48)$$

$q_A - q_A(p_A^R)$ decreases in price.

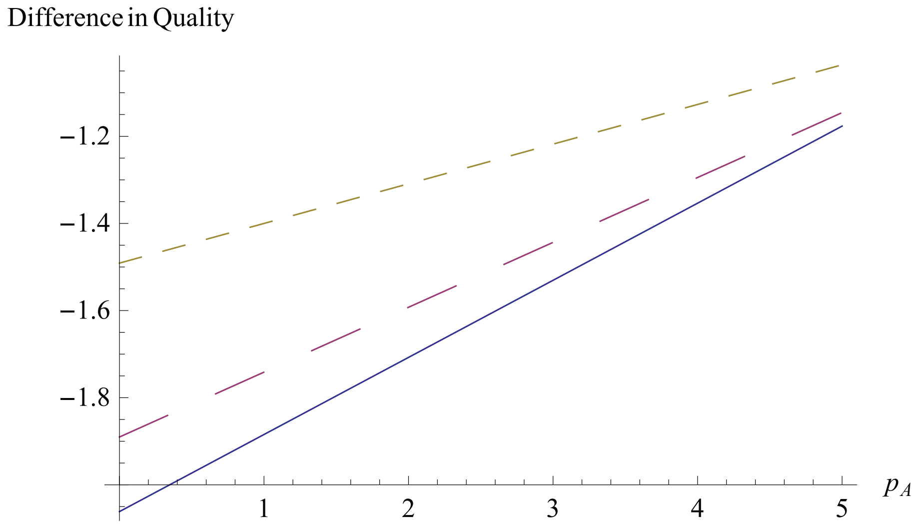
$$q_S - q_S(p_A^R) = \frac{1}{AB}(10.21(-1.77 + \gamma)(8.46 + \gamma) - 0.003A(-1.54 + \gamma)(8.21 + \gamma)Bp_A) \lesseqgtr 0 \quad (4.49)$$

With: $A = (17.22 - \gamma)$ $B = (29.14 + \gamma)$ $q_S - q_S(p_A^R)$ increasing, in this example, in price as long as $\gamma < 1.54$. For $\gamma < 1.54$, the difference is negative in this example indicating that in the regulated setup, the unregulated market has a higher outcome in quality.

$$Q_{Total} - Q^R_{Total} = \frac{\begin{array}{c}75.74A(0.52 + \gamma)(6.76 + \gamma)B \\ -0.02(A^2(0.60 + \gamma)(6.71 + \gamma)(849.25 + \gamma(58.28 + \gamma))p_A\end{array}}{A^2B^2} \quad (4.50)$$

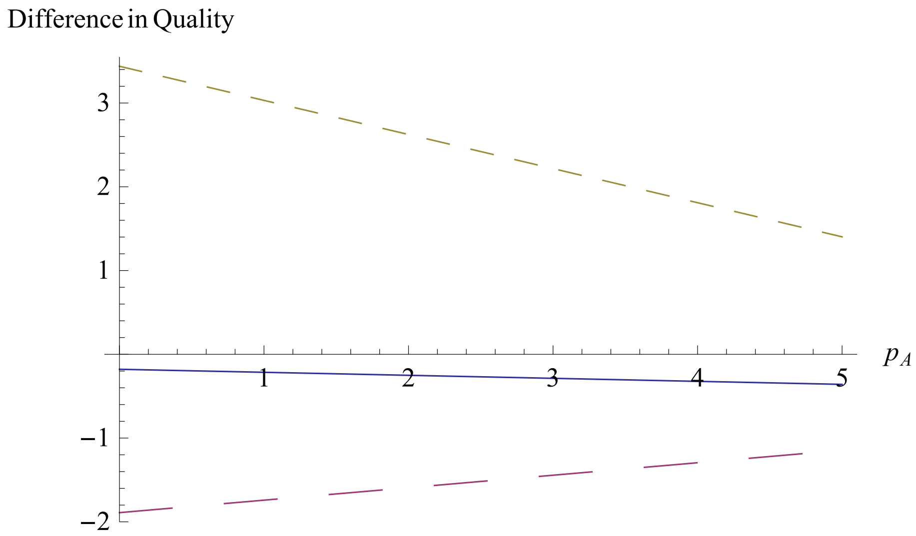
The graph shows that for $Q_{Total} - Q^R_{Total}$ the influence of p_A is negative, however, with a positive value. The graphs show that different constellations are possible.

Figure 4.5: Quality in Complementary Services



Note: The lines indicate the difference between investment in complementary services $q_S - q_S(p_A^R)$ in an unregulated and a regulated setup. The narrow dashed line indicates a high γ, the wide dashed a medium γ and the bold line a low γ.

Figure 4.6: Total Quality



Note: The lines indicate the difference between between total quality$Q_{Total} - Q_{Total}^R$ in an unregulated and a regulated setup. The narrow dashed line indicates a high γ, the wide dashed a medium γ and the bold line a low γ.

5 An Empirical Analysis of Internet Broadband Use and Firm Success[1]

5.1 Introduction

The finding that the adoption of information and communication technologies (ICT), as already discussed in the introduction of chapter 3 and widely in the literature, had a severe and positive impact on firm performance (Draca et al. 2007, Van Ark et al. 2008, Jorgenson et al. 2008), has been used as a starting point in many studies, for instance Bertschek and Meyer (2010, pp. 1, 2), investigating particular aspects of the impact of ICT. Their study, as well as many others (e.g., Bertschek and Meyer 2010, pp. 1, 2, Draca et al. 2007, pp. 105-106; see also Czernich et al. 2009 pp. 1-2, 4-5, who claim this for broadband Internet, which is "a subset of ICT"[Holt and Jamison 2009, p. 575]), link this severe and well documented impact to the characterization of ICTs as "General Purpose Technologies"(Bresnahan and Trajtenberg 1995, p. 83; GPT)[2], that "enable firms to reshape and to optimize their business processes"(Bertschek and Meyer 2010, p. 2).[3] It is widely observed also in the literature (e.g., Holt and Jamison 2009, p. 575) that to take advantage of the potential benefits of ICT, policy makers consider the availability of an efficient broadband Internet communication infrastructure to be essential (e.g. Federal Communications Commission 2010, European Commission 2010, Bundesministerium für Wirtschaft und Technologie 2009), whose claims and also the possibility to further gains from ICT due to broadband have also been discussed, and also used as a starting point, by several scientific studies (Holt and Jamison 2009, Koutroumpis 2009, Czernich et al. 2009). Broadband Internet is defined as Internet access provided at a certain high speed level with

[1]This chapter is based on joint work with Irene Bertschek and Daniel Cerquera, both from the Centre for European Economic Research (ZEW), Mannheim. It is based on the project "The role of broadband Internet for corporate success" commissioned by the Deutsche Telekom AG. The chapter is based on and published in an only slightly differing project report (Bertschek et al. 2010), on and in an only slightly different discussion paper version (Bertschek et al. 2011) as well as in an unpublished feasibility study that also has major elements in common. Versions of this work have been presented at different conferences and seminars: 2nd ICTNET Workshop ICT, Intangibles and Innovation, London 2011, the European Association of Research in Industrial Economics (EARIE), Stockholm 2011, the ITS European Regional Conference of the International Telecommunications Society 2011 (ITS), Budapest. We would like to thank all participants, anonymous referees as well as Francois Laisney, Mark J. McCabe, Martin Peitz and Glenn Woroch for valuable comments and suggestions. The opinions expressed are those from the author. All errors are mine.

[2]See that all the mentioned papers cite and refer to the GPT term and to Bresnahan and Trajtenberg (1995). As all these paper cite them, we do not cite the citing, but only the original source.

[3]See Bertschek and Meyer (2010, pp. 1, 2) referring to the argument of Brynjolfsson and Hitt (2000) and Brynjolfsson and Saunders (2010) that those innovations may drive future productivity.

the particular definitions being heterogeneous and covering a large range of actual speed levels (OECD 2009, p. 90).[4] However, as it is widely discussed, in many regions even across US states or European countries Internet access is not available at any speed that can be defined as broadband such that fostering the availability of such infrastructures therefore has been declared a policy objective of European countries as well as of the USA (Federal Communications Commission 2010, European Commission 2010, Bundesministerium für Wirtschaft und Technologie 2009).[5]

Even though the benefits of broadband Internet are undisputed among policy makers, empirical evidence on the benefits is inconclusive. A causal, positive effect of telecommunications infrastructure on economic performance has already been presented in the literature (Roeller and Waverman 2001). There are some studies (Koutroumpis 2009, Czernich et al. 2009) showing positive effects of broadband on productivity and growth at the aggregate level. By contrast empirical evidence on the causal impact of broadband on firm performance is still lacking.

This chapter provides evidence on the causal impact of broadband Internet on the economic firm performance using survey information of German firms (ZEW ICT Survey, ZEW 2002, ZEW 2004, by the Centre of European Economic Research, ZEW), for the years 2001 and 2003 that has been used by several authors as well (e.g., chapter 3, Ohnemus 2007, p. 16, 2009, pp. 12-13, Bertschek and Meyer 2010, p. 7). To capture different dimensions of firm success, we use performance in terms of labor productivity as well as realized product and process innovations (see, also using similar measures with this survey, Ohnemus 2007, p. 9, Bertschek and Meyer 2010, p. 7). Besides information on many dimensions of determinants of firm success it includes the use of broadband Internet by firms (see description in chapter 3, Ohnemus 2007, p. 16, 2009, pp. 12-13, Bertschek and Meyer 2010, p. 7). The timing is of special importance as it focuses on the early phase of the DSL expansion in Germany (from 2001 to 2003). This allows us to exploit differences in the rate of broadband usage across German firms.

Given that broadband usage may be influenced by the actual firms' economic performance (i.e. reverse causality), an instrumental variable approach is used to control for potential endogeneity of broadband usage at the firm level. In order to identify the causal impact of

[4] For instance, the OECD defines the lower bound of broadband Internet as Internet access with speeds above 256 kbits per second. However, they do also distinguish between different speeds in their analysis (OECD 2009, p. 90) that are by far more rapid.

[5] For instance the Federal Communications Commission (2010) has published a detailed broadband strategy, the (European Commission 2010) has broadband deployment as one goal in its Europe 2020 strategy and the German Federal Ministry for Economy and Technology (Bundesministerium für Wirtschaft und Technologie 2009) announced broadband deployment as a policy objective, too.

broadband Internet infrastructure on economic performance at the firm level, this chapter takes advantage of regional differences in Germany. We use DSL availability at the postal code level as instrumental variable. In particular, we used the time lag (in days) between the deployment time for the postal code where a firm is located and a benchmark date. Even for adjacent postal codes within a given area, the data shows high variability.

The chapter provides two main results. First, even though a positive correlation between productivity and the use of broadband Internet is revealed by the data, this effect is not robust controlling for endogeneity and different sources of variation. Using an instrumental variable approach, we show that the impact of broadband Internet on firms' labor productivity is highly heterogeneous among German firms and not statistically different from zero. Secondly, the impact of broadband Internet on firms' innovation activity is positive, significant and is robust to different specifications. It suggests in line with the literature (e.g., Bertschek and Meyer 2010, pp. 1, 2, or Draca et al. 2007, pp. 105-106) that broadband Internet allowed firms to innovate.

The chapter is, as it is common, organized as follows. Section 2 provides a background discussion and related literature, section 3 describes the empirical strategy, section 4 presents the data. Section 5 provides the main empirical results. Section 6 concludes.

5.2 Literature Review and Background Discussion

The literature provides evidence on the impact of telecommunications and broadband Internet infrastructure on economic performance. The starting point for studies analyzing the particular economic impact of telecommunication technology investment is the study of Roeller and Waverman (2001), who demonstrate that telecommunication use (approximated with telephone lines per inhabitant) increased GDP for a panel of OECD countries.[6] The main feature in that study is that they use a structural approach against possible bias due to endogeneity (Roeller and Waverman 2001, pp. 914-917).

This particular impact of broadband Internet is, for instance, shown in the similar study by Koutroumpis (2009), who takes advantage of the strategy of the study of Roeller and Waverman (2001) and uses their approach, however, using broadband variables instead of telephone lines and a later timing of their panel between 2001 and 2007, to show a positive causal effect of broadband use on GDP growth. The main feature in his study is that he

[6]This study is the most prominent study for the literature on the impact of telecommunications on growth and also a starting point for the studies discussed in the following by Czernich et al. (2009) and the study of Koutroumpis (2009).

can translate the Roeller and Waverman (2001) findings to broadband Internet showing causal evidence.

Another study, is the of Czernich et al. (2009), who provide an empirical study at an aggregated level regarding the impact of broadband Internet on economic growth in OECD countries. They relate their study explicitly to the general literature of the proven positive benefits of ICT and the possible characteristics of broadband Internet as a GPT (Czernich et al. 2009, pp. 1-2, 4-5).[7] They use an Instrumental variable approach revealing a positive broadband Internet effect (Czernich et al. 2009, p. 2). They use a specific period that allows them to capture the whole diffusion process of broadband Internet, which they take advantage of to generate their instruments (Czernich et al. 2009, pp. 2-3). This feature and the link to the GPT is interesting as for instance Draca et al. (2007, pp. 105-106) claims in relating to the general GPT argument of Bresnahan and Trajtenberg (1995) that for ICT in general the "adoption of a GPT entails experimentation"(Draca et al. 2007, pp. 105) and "spillover effects"(Draca et al. 2007, pp. 105). This means, especially due to "experimentation"(Draca et al. 2007, pp. 105), that more efficiency is not certain and necessarily provided directly, but requires time of which Czernich et al. (2009, pp. 2-3) take advantage of. This point is also relevant for our study as we consider a rather early period of time as well.

Before that two studies that were able to attribute causal evidence of the impact of broadband Internet on economic performance, there were many studies that tried to uncover the impact of broadband Internet on economic performance (See, Czernich et al. 2009, pp. 5-6, discussing two earlier studies that were not able to provide robust evidence, as well as Holt and Jamison 2009, for a survey), but as Holt and Jamison (2009, p. 580) summarizes this literature and the evidence, in particular for the US, these studies provide some hints "that broadband has a positive economic impact, but that impact cannot be analyzed with any precision"(Holt and Jamison 2009, p. 580).[8] Beside those scientific studies, different earlier consultancy studies (Fornfeld et al. 2006, Fornfeld et al. 2008) tried to find positive links between Internet broadband and economic performance, i.e. job growth and GDP growth, however without providing strong evidence.

All these studies cannot provide evidence of the impact of broadband Internet at the firm level. It cannot be shown how exactly possible benefits of broadband technology arise

[7] See also the mentioned sources in the introduction.

[8] See in particular Czernich et al. (2009, pp. 4-5) referring and criticizing Gillett et al. (2006) and Crandall et al. (2007), discussing that they cannot provide causal evidence.

and are translated into economic performance, which is essential for assigning economic impact to the diffusion of broadband.[9]

In a summary, the literature on broadband suggests that broadband Internet may lead to an increase of economic performance in areas where it is deployed and used (Roeller and Waverman 2001, Koutroumpis 2009, Czernich et al. 2009, Polder et al. 2009). Literature dealing with the impact of ICT on performance (e.g., Draca et al. 2007, Van Ark et al. 2008, Jorgenson et al. 2008) also shows that broadband Internet use may lead to an increase in productivity of firms as well, but also to an increase in innovations (Draca et al. 2007, pp. 105-106).[10] Due to its GPT characteristics as discussed above benefits, i.e. efficiency, may not arise directly but may require time, which we expect to be of special importance due to the early timing in the diffusion process of our study (Draca et al. 2007, pp. 105-106).

5.3 Empirical Strategy

The main objective of the analysis is to investigate the impact of broadband Internet use on firm performance, which we measure, taking into account the GPT argument made by Draca et al. (2007, pp. 105-106), in different dimensions, labor productivity and success in process and product innovations to capture long as well as short run impacts. This chapter is interested in the impact of the broadband adoption itself. The main issues considered in the empirical strategy are the typical issues for empirical investigations, endogeneity and an exact identification of the relevant issues (e.g. Buccirossi et al. 2009, Aghion et al. 2009). We organize the problem in the typical form first presenting the econometric implementation and then the accordingly the identification that is achieved via instruments as for instance also done by Aghion et al. (2009) or Buccirossi et al. (2009).

5.3.1 Econometric Implementation

Estimation for productivity and innovation has to consider differences in the functional forms, however, the general variables are nearly identical. First, we estimate the labor

[9]See, however, for an exception Polder et al. (2009), who do not reveal a causal impact for firms, but show important correlations.

[10]See, also, as mentioned above Bertschek and Meyer (2010, pp. 1, 2) relating to complementary innovations that allow “firms to reshape and to optimize”(Bertschek and Meyer 2010, p. 2) themselves. See, also, Brynjolfsson and Hitt (2000) as well as Brynjolfsson and Saunders (2010) to which Bertschek and Meyer (2010, pp. 1, 2) also refers to for productivity gains due to ICT.

productivity and then innovation. Analogous to Aghion et al. (2009, p. 22), who analyze the impact of entry on the same two different kinds of performance measures (innovation and productivity), to discuss the common patterns in both estimations, we summarize the equations first in a general functional form that uses an undefined functional representation f instead of the different particular functional forms and discuss in the following subsection the identification strategy analogously focusing on our instrumenting strategy (similarly, Aghion et al. 2009, p. 22). Those representations are given as in Aghion et al. (2009, p. 22) afterwards. Besides those different performance measures as in Aghion et al. (2009), we also tackle the same typical and nearly universally given identification issues in empirical work, also discussed by them, as endogeneity and correct unbiased extraction of the effect of interest (Aghion et al. 2009, p. 22). The general form we use to represent our model, is analogous to Aghion et al. (2009, p. 22):

$$Y_{i,t} = f(BB_{i,t-1}, ICT_{i,t-1}, X_{i,t-1}) \tag{5.1}$$

Following Aghion et al. (2009, p. 22), in this equation, the $Y_{i,t}$ represents either labor productivity, product or process innovation of firm i at time t.[11] The f is also used by Aghion et al. (2009, p. 22) to represent an undefined functional form explained later for the different estimation equations. As in Aghion et al. (2009, p. 22) we now introduce our explanatory variables, with $BB_{i,t-1}$ indicating whether a firm uses broadband Internet or not and $ICT_{i,t-1}$ controlling for the ICT infrastructure within the firm to avoid that the effect we are interested in, broadband Internet, reflects general ICT use. This is important, as this variable can be seen as “a subset of ICT”(Holt and Jamison 2009, p. 575). Similar to common notation and also used similarly in Aghion et al. (2009, p. 22), $X_{i,t-1}$ is a vector including various controls relevant for economic performance at the firm level (see, similarly, Aghion et al. 2009, p. 22). In our particular problem, we control for regional controls as production inputs and other observable characteristics that are commonly used in the literature, as a firms qualification structure and the firms experience in innovations (e.g., Bertschek and Meyer 2010, p. 6, using also the ZEW ICT survey controlling in their innovation estimation similarly for qualification and firms experience in innovation).[12] Similar to chapter 2, chapter 3 and analogous to Aghion et al. (2009, p. 22) there is a lag in the timing of dependent and independent variables (with the dependent variables having the index $t = 2003$ and the explanatory variables the index $t - 1 = 2001$).

[11] Similar measures for success, are widely used in the literature. For instance, Bertschek and Kaiser (2004, p. 398) for labor productivity and Polder et al. (2009, pp. 9-10) for those innovation measures.

[12] See Bertschek and Meyer (2010, p. 6) in particular using the argument of persistence in innovation by Peters (2009).

As mentioned above, for the particular estimation, after the general patterns of the estimation we now describe analogous to Aghion et al. (2009) the particular labor productivity and innovation estimation equations captured in the previously undefined functional form f.[13] In contrast to Aghion et al. (2009, p. 22), we estimate overall labor productivity, while they estimate "growth of labor productivity"(Aghion et al. 2009, p. 22). In addition, while they use a panel, we estimate a cross section using two waves of a survey. Our measure is the ratio sales per employee ($Y_{i,t}/L_{i,t}$), which is estimated using a derivation of a standard Cobb-Douglas production function:[14]

$$ln(Y_{i,t}/L_{i,t}) = A_{i,t-1} + \beta_C ln(C_{i,t-1}) + (1-\beta_L)ln(L_{i,t-1}) + \beta_{BB}BB_{i,t-1} + \beta_X X_{i,t-1} + u_{i,t} \tag{5.2}$$

With the typical notation with $A_{i,t-1}$ for the Total Factor Productivity, $C_{i,t-1}$ for capital, $L_{i,t-1}$ for labor and the already described explanatory variables.[15]

Our estimation on output of innovations differs to Aghion et al. (2009) as well. While they use as an output "patents"(Aghion et al. 2009, p. 22), we estimate either product and process innovations that do not necessarily require a patent (see, the empirical strategy regarding innovations, Aghion et al. 2009, pp. 22-23). In turn, an estimation of the impact of broadband on innovation takes the binary character of the two innovation performance measures ($Y^j_{i,t}$) into account, which requires a different functional form in contrast to the productivity setup and estimates it differently with a Probit model (see, e.g., using an analogous estimation for binary process innovations Bertschek and Meyer 2010), which relates to the large literature investigating success in innovations.[16] The explanatory variables are similar to other studies estimating innovation with the ICT survey (e.g., Bertschek and Meyer 2010) or, however with less information to the similar, but more

[13]See similar Aghion et al. (2009, p. 22) first describing the general functional form and then turning to the particular estimation equations for labor productivity and then on patents.

[14]The Cobb-Douglas Production function is standard in the literature and for instance similar used with the same labor productivity definition and the necessary reformulation by Ohnemus (2009, pp. 9-10), Ohnemus (2007, p. 9) or Bertschek and Meyer (2010, pp. 5-6).

[15]The $ICT_{i,t-1}$ variables are included in the $X_{i,t-1}$ in this representation to improve readability. This specification does not consider intermediate inputs, which clearly leads to less precision. The data availability for this particular time, however, is rather limited and reduces the sample size significantly such that consistent and efficient estimations are not possible using intermediate inputs. In addition, the survey does not provide information on capital. Therefore, we use investment as a proxy for capital implicitly assuming that investment is equal to the rate of depreciation and proportional to the true amount of capital, which has been also done similarly e.g. by Ohnemus (2007, p. 18) and Bertschek and Kaiser (2004, p. 398). See that Ohnemus (2007, p. 18) explicitly refers to Bertschek and Kaiser (2004, p. 398), however also to additional work of the first of the two authors, when defending his strategy.

[16]See, as already discussed in chapter 3, other studies on innovations using a similar setup: Bertschek and Meyer (2010, p. 6), Polder et al. (2009, pp. 9-10), however estimating different kinds of innovation jointly, Peters (2009, pp. 232-233), however using a more sophisticated panel. As already stated in chapter 3, there exist a large body of literature.

detailed, Mannheim Innovation Panel (e.g. Peters 2009, Hottenrott and Peters 2009). The relationship is, as already stated similar to Bertschek and Meyer (2010, p. 6) and related to Polder et al. (2009, pp. 9-10)[17] and specified with a Probit (analogous to Cameron and Trivedi 2005, p. 465):

$$\Pr[Y^{j}_{i,t} = 1|x] = \Phi(\beta_{BB}BB_{i,t-1} + \beta_X X_{i,t-1} + u_{i,t}) \tag{5.3}$$

with $j \epsilon \{PZ, PD\}$.

5.3.2 Identification Strategy

In order to identify the impact of broadband Internet use on firm performance we rely on the ZEW ICT survey of the years 2002 and 2004 (ZEW 2002, ZEW 2004). Broadband Internet is defined as a firm's use either of leased lines, or DSL broadband. We restrict the timing to these particular surveys because with approximately 60 percent of broadband using firms in 2002, there is a significant variation in the broadband adoption. This ensures sufficient variation in broadband Internet use. In addition, the impact of broadband Internet at a later stage with almost universal adoption is driven by specific ICT solutions and not by the adoption decision. This chapter is interested in the impact of the broadband adoption itself.

The use of broadband Internet is a firm strategy, that may possibly endogenous with respect to firm performance strategy, which may, similar as in Aghion et al. (2009, p. 22), imply endogeneity.[18] In particular, as it is common knowledge, high performing firms may be more likely to adopt new technologies than firms with a lower performance, such that the direction of the impact is not clear.[19] This issue is tackled by instrumenting broadband Internet use with DSL broadband availability defined as the time lag (in days) between the deployment time for the postal code where a firm is located and a benchmark date (Data: Deutsche Telekom (2009)) which are the typical issues for instance also used in the Aghion et al. (2009) or Buccirossi et al. (2009) paper. Therefore, as in the Aghion et al. (2009) paper, our identification relies on the typical two features: using a lag in the explanatory variables as well as instrumenting the endogenous variable (e.g., Aghion et

[17]However, consider as already stated that Polder et al. (2009, pp. 9-10) does not estimate a common Probit, but three binary innovation equations jointly.

[18]Consider that we solve this problem as stated above as they do by lagged variables as well as instruments (see, Aghion et al. 2009, p. 22). However, this is standard in the literature (e.g., Buccirossi et al. 2009, pp. 8-10)

[19]Even though we use lagged values from the previous survey (see, similarly, Aghion et al. 2009, p. 22), this lagged variables are not sufficient to exclude simultaneity of the broadband Internet use variable and the innovation variables.

al. 2009, Buccirossi et al. 2009, Czernich et al. 2009, Griffith et al. 2010), of which the later is the interest of this section. Because DSL is the most widely used broadband technology in the data, DSL availability is highly correlated with actual broadband Internet use. Given the important regional differences within the early phase of the DSL expansion, the instrument has a large variation that we exploit to consistently estimate the effect of broadband Internet. This variation in the broadband availability is important because it is exogenous to the firm. Although the expansion is related with regional economic development and demographics that could be related to firm strategies and performance, the analysis uses the variation in deployment at the very disaggregate postal code level.[20] That is, within a given area (i.e. Bavaria), there was a high variation in the actual timing of deployment across postal code areas. The data shows high variability even for adjacent postal codes within a given area. Therefore, the conditions for DSL availability to be a proper instrument are presumably fulfilled, as it is correlated with actual broadband use, but independent regarding firm decisions. This implies that it is exogenous to the performance measure.

The continuous structure of the instrument and the binary structure of the endogenous variable has to be considered. We do so in the productivity estimation using a methodology according to Wooldridge (2002, p. 623). This method uses the endogenous variable $BB_{i,t-1}$ and the instrument DSL availability, *Availability*, as an explanatory variable with a Probit for $Pr[BB_{i,t-1} = 1|x, Availability_{i,t-1}] = G_{i,t-1}(X_{i,t-1}, Availability_{i,t-1})$ first, and then uses the predicted value $\hat{G}_{i,t-1}$ as the instrument in a common instrumental variable estimation using the general method of moments method (Wooldridge 2002, p. 623). In the following, $X_{i,t-1}$ corresponds to a vector of all covariates included in the estimation[21], excluding broadband Internet use. Importantly, we also instrument production function inputs, capital and labor, with their corresponding lagged values to reduce possible endogeneity. Instruments are used in first stage estimations, the results of which are used in the corresponding second stage to estimate their impact on labor productivity.

The estimation of the innovation effects relies on a recursive bivariate Probit, which uses the variable *Availability* as an instrument.[22] In particular, it estimates with a maximum-likelihood a model of the form analogous to the model specified in Maddalla (1983, p. 122):

$$BB_{i,t-1} = \theta X_{i,t-1} + \omega Availability_{i,t-1} - u_{i,t-1}$$

[20]In particular postal code areas in Germany are organized in a five digit postal code. We can identify availability for each particular postal code area.

[21]$X_{i,t-1}$ also includes the variable ICT_{t-1} and the production inputs.

[22]This model is discussed in detail in Heckman (1978), Maddala (1983, pp. 122 - 123), Angrist and Pischke (2009, pp. 197-204), Greene (2008, pp. 823-826).

$$Y_{i,t}^{j} = \beta X_{i,t-1} + \gamma BB_{i,t-1} - z_{i,t-1} \tag{5.4}$$

with $j \epsilon \{PZ, PD\}$

However, quantification of the effects requires in this model calculation of marginal effects.[23] There are different possibilities to uncover these effects. First the conditional marginal effects at the mean given that a firm innovated and used broadband can be computed analogous to the formulation of Rhine et al. (2006, p. 151):

$$MFX = \frac{\delta Prob(Y_{i,t}^{j} = 1, BB_{i,t-1} = 1)/\delta z}{Prob(BB_{i,t-1} = 1)}$$

$$+ \frac{-Prob(Y_{i,t}^{j} = 1, BB_{i,t-1} = 1) * (\delta Prob(Y_{i,t}^{j} = 1, BB_{i,t-1} = 1)/\delta z)}{(Prob(BB_{i,t-1} = 1))^2} \tag{5.5}$$

with z corresponding to the variable the marginal effects are computed for (Rhine et al. 2006, p. 151). This effect, however, focuses on the firms, which use broadband. This means that only a selected group is considered here. Therefore, we compute the "average causal effect"(Angrist and Pischke 2009, p. 200) of broadband Internet on the used innovation measure, indicating the effect broadband Internet use has on average, including users and non users analogous to Angrist (2001, p. 14)[24]:

$$ACE = \Phi(\beta X_{i,t-1} + \gamma BB_{i,t-1}) - \Phi(\beta X_{i,t-1}) \tag{5.6}$$

The standard errors are then calculated using the delta method.[25] These methods allow us to consider the rich variation in the data to estimate consistently the desired effects.

5.4 Data

We use similar to chapter 3, the ZEW ICT survey (ZEW 2004, ZEW 2007), however, now for the years 2002 and 2004, which has also been used and described by several other authors as well (e.g., chapter 3, Ohnemus 2007, p. 16, 2009, pp. 12-13, Bertschek and Meyer 2010, p. 7).[26] To complement the information of the survey, we use additional data sources, which are presented in the following data description.

[23]See for this as for the model in general as mentioned above Heckman (1978), Maddala (1983, pp. 122 - 123), Angrist and Pischke (2009, pp. 197-204), Greene (2008, pp. 823-826).

[24]The formula is standard and described and discussed in detail in Angrist and Pischke (2009, pp. 197-204). The particular reformulation has also been used in Angrist (2001, p. 14)

[25]See for instance Greene (2008) for a discussion of the delta method.

[26]Most of the surveys questions are retrospective and regard the years 2001 and respectively 2003.

5.4.1 Performance Measures

The performance measures used in the analysis are twofold, first a labor productivity as a productivity measure is provided and secondly two innovation measures are given. The information is from the ICT survey (ZEW 2002, ZEW 2004). Labor productivity is defined as it is common in the literature as sales per employee (see, Bertschek and Kaiser 2004, p. 398 as well as the discussion on productivity measurement in chapter 3 and the referred to discussion in Syverson 2004, p. 539).[27] The average value of labor productivity is provided in table 5.1, indicating a value of 0.19 million Euros of sales per employee.[28] Secondly, we observe whether a firm had successful innovation activity within the years 2001-2003 (See, e.g. similarly Bertschek and Meyer 2010, p. 7, using the same process innovation variable as a measure of success. The product innovation variable represents the same question, but for product innovations. Peters 2009, pp. 240, 241 uses a combined process, product innovation combination, with similar variable definitions, to control for innovation output as well, or Polder 2009, pp. 9-10, using product and process innovations, but estimating those jointly.). We consider two types of innovation: process and product innovation. Both variables are dummies indicating either realized product or process innovations. Data shows a wide realization of either product or process innovations. In particular, 75% of all firms made process innovations between 2001 and 2003, while 65% made product innovations within that time.

5.4.2 Main Explanatory Variable and Instrument

The main explanatory variable is broadband Internet use (ZEW 2002). This variable is defined as an indicator whether a firm either uses DSL Internet access or a leased line in 2002. DSL Internet access provided at this time at least an Internet access speed of 768 kbits per second, which is clearly above the lower bound of the OECD broadband definition of 256 kbits per second (OECD 2009, p. 90). Importantly, DSL has been at this time, beside leased lines for larger firms, the dominant broadband technology capturing nearly the entire market.[29] The broadband use variable therefore is a dummy and indicates that 61% of all firms in the sample were actually using broadband Internet (table 5.1).

[27]The literature, however, often prefers value added as an output measure (e.g., Aghion et al. 2009, p. 24, Syverson, p. 539), Ohnemus 2009, p. 13, however, with the data we have, we cannot provide reliable information on this

[28]As there are some large firms, which are presumably outliers and subject to measurement error, we drop the 5 percent of the largest firms in the estimates.

[29]The only other broadband technologies at this time were satellite connection and powerline. Both were not relevant for the firms in the sample.

Due to possible endogeneity of this variable, as discussed in the previous subsection, we use information on regional DSL broadband Internet availability to instrument actual broadband usage. Because DSL is the dominant broadband Internet technology at this time and the availability of backbone infrastructure needed for DSL broadband Internet also facilitates and reduces prices for the use of leased lines,[30] we suppose the regional DSL availability as a good predictor for broadband Internet use. Furthermore, the DSL availability is exogenously determined by the telecommunications provider and not influenced by the firm and its strategies. Therefore, DSL availability is supposed to be a proper instrument.

DSL availability is defined as the time lag (in days) between the deployment time for the postal code where a firm is located and a benchmark date (31 December 2001).[31] It is constructed by data provided by the German telecom incumbent, Deutsche Telekom AG (Deutsche Telekom 2009). In particular, data contains information on regional communication distribution centers and when those have been equipped with DSL technology. The availability variable indicates DSL availability in the communication distribution center's postal code area. The variation in DSL roll out, which began in 2000 (table 5.2), supports the choice of the particular surveys for the analysis.[32] It can be seen that in the time we are interested in, DSL was made available in most of the relevant postal code areas.[33] In particular, until the end of 2001, in 75.57% of the data's postal code regions, DSL was available. Furthermore, table 5.3 provides detailed information on the DSL availability variable. It shows the mean and different percentiles of days of DSL availability before the 31 December 2001. The mean of all observations within the sample is 332 days of DSL availability. The 25% percentile has only 180 days, the median 328 and the 75% percentile 458 days of availability. The 90% percentile even has 607 days DSL availability. This indicates that our measure of availability has a large variation.

5.4.3 Further Control Variables

As pointed out above, we try to control for other ICT related factors, for which we use the ICT survey (ZEW 2002, ZEW 2004). Their descriptive statistics are presented in

[30] The results derived in the following sections are also robust if we exclude the observations for leased lines.

[31] In the estimations, we divide this variable by 365 to show years of availability. This, however, is without loss of precision or changes in the size of effects, but increases coefficients, such that the interpretation becomes more convenient.

[32] DSL deployment in Germany began for a couple of test regions in 1999, but officially started in 2000.

[33] We only consider postal code regions in which we know that a DSL main distribution center is located. We do not know if this distribution center also provides partially another postal code area with DSL.

table 5.1. Firms' general ICT intensity is captured by the percentage of workers using mainly PCs at work.[34] On average, 52% of a firm's workers using mainly a PC. Besides this, information on whether firms use other firm specific ICT Systems like Supply Chain Management (SCM), which is the case for 22%, and Enterprize Resource Planning (ERP) systems, which is the case for 77% of the firms, are available as well (other studies use this survey information as well, e.g., Engelstätter 2009, p.10). Other control variables provide information on firms' general characteristics. The average number of employees is 166, the average investment is 1.9 million Euros (this variable is used always in production functions [e.g. Bertschek and Kaiser 2004, p. 397] and also commonly in innovation estimations [e.g. Peters 2009, p. 234]). Moreover, we have information on the skill structure indicated by the share of high skilled workers, which is on average 21% (see, similarly, e.g. Bertschek and Meyer 2010).[35] Additionally, a set of binary controls for location either in East or West Germany (21% of firms all are located in Eastern Germany), exporting behavior (53% of all firms export) and 14 industry dummies (see, using similar controls and definitions using the same survey, with the same industry classification, Ohnemus 2007, Ohnemus 2009, Bertschek and Meyer 2010).[36] To control for regional disparities, we use a set of 10 regional dummies controlling for the general postal code area. The reasoning is that the regions may differ in respect to their industry structure with firms of different regions of the same industries located at different parts along the value chain. This control ensures that variation used by the instrument does not only capture regional performance arbitrarily correlated with Internet availability. To add more information on regional economic characteristics, we are using a database INKAR (Bundesamt für Bauwesen und Raumordnung 2008), which contains regional information within Germany. The database is provided by the the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesamt für Bauwesen und Raumordnung 2008). We use information of the GDP per capita on a county level, as a more quantitative measure for regional performance than the postal code dummies.

[34]See similarly Bertschek et al. (2010, p. 7) or Ohnemus (2007, p. 15), calling this variable similarly "The share of workers predominately working at a PC"(Bertschek et al. 2010, p. 7) ,"share of employees working mainly at a computerized workplace"(Ohnemus 2007, p.16).

[35]The use of the highly qualified variable indicates testing the effect of highly qualified against those with either vocational training or no qualification.

[36]Consider that the referred to authors not use exactly the same controls, but all do take account of location, one of exporting behavior, however with a ratio, (Ohnemus 2007) and two of the same industry controls (Ohnemus 2007, Bertschek and Meyer 2010).

5.5 Empirical Analysis

5.5.1 Descriptive Statistics

To uncover general patterns in the data and important correlations, table 5.1 shows that the performance measures as well as firm characteristics are correlated with broadband Internet use. Regarding firm characteristics, the table shows that 61% of all firms used broadband Internet in 2001. Firms in the overall sample had on average sales of 79.08 million Euros in 2001. However, those with broadband had 116.5 million Euros sales, and those without broadband only had 18.98 million Euros sales. Evidently, the firms using broadband Internet have higher sales. The same pattern applies for size measured in employees. While the average number of employees in the sample in 2001 is 166, broadband using firms employ at the mean 205 persons while not broadband using firms employed 95. Not surprisingly, ICT intensity is correlated positive with broadband Internet use, too. While firms using broadband Internet have a mean of 59% of the employees working mainly with a PC, those without broadband use are less ICT intense with only 40% of employees working mainly with a PC. Therefore, it can be summarized that firms using broadband are larger, have a higher output and are more ICT intense.

The firms which use broadband differ from those not using broadband regarding their performance measures, too. While the difference in labor productivity is rather small with 0.18 millions per employee for firms without broadband Internet and 0.2 millions for firms with broadband, differences in innovative performance are larger. In the whole sample, 65% of the firms made product innovations between 2003 and 2001. However, while the percentage for broadband Internet using firms is 71%, it is only 57% for firms not using broadband Internet. The same can be observed for process innovations between 2003 and 2001. While the average in the sample is 75%, only 68% of all firms not using broadband made process innovations, while 80% of those who used it did. This leads to the supposition that broadband Internet may be related to a higher performance, measured either in labor productivity or success in innovations.

5.5.2 Econometric analysis

Table 5.5 shows the results from the estimation of the production function outlined in equation 5.2. Column (1) presents the results from an OLS specification, controlling for the firms main inputs of production and additional controls, including regional variables. The estimation shows a positive and significant relationship between the use of broadband

Internet and labor productivity at the firm level. This result is not surprising given the potential embedded in a broadband Internet infrastructure at the firm level, as it can facilitate certain operations within the firm (i.e., e-Commerce and global networking) (Czernich et al. 2009, p. 4).

Given that the decision whether to use broadband Internet or not may be subject to reverse causality, columns (2)-(6) follow an instrumental variable strategy in order to derive consistent estimates.[37] In particular, the specification presented in column (2) estimates the impact of broadband Internet on labor productivity, controlling for the firms' inputs and additional controls (economic activity, location and export activity). It shows a positive and highly significant impact of the use of broadband Internet. However, it should be noted that the estimation results exhibit a wide confidence interval on Internet broadband that includes zero.

In consequence, the columns (3)-(6) extend the analysis by including additional information that can be related to the decision to adopt broadband Internet at the firm level. In particular, column (3) includes information regarding the ICT infrastructure within the firm. Given that more ICT intensive firms are more likely to adopt broadband Internet, the previous result might be reflecting a preference for ICT solutions not necessarily related to the adoption of broadband Internet. Interestingly, after controlling for ICT intensity (i.e., percentage of employees working mainly with a PC), the impact of Internet broadband on labor productivity remains positive and significant. Consistent with existing literature, the intensity of ICT positively affects labor productivity at the firm level.

Column (4) investigates whether the quality of the labor force (i.e., percentages of employees with university degree) and the firms' innovative experience (i.e., product innovation introduced to the market in the past) is driving the results. In this specification, the impact of broadband Internet on labor productivity remains, as before, positive and significant. Column (5) controls for additional variables related with the ICT infrastructure. By including information on the adoption of ERP and SCM systems, the analysis tries to capture whether the impact of broadband Internet is driven by specific ICT applications probably enhanced by the use of high-speed Internet. This does not seem to be the case, as the results remain unchanged.

Even though the results presented in columns (3)-(5) show that the positive impact of broadband Internet is robust regarding the introduction of additional information. This impact remains highly heterogeneous as the confidence intervals contain zero for all specifi-

[37]The Wald endogeneity test holds in all specifications so that we suppose that there is endogeneity. Therefore an IV strategy is necessary to derive consistent estimates.

cations. Finally, column (6) introduces regional variables in order to control for the role of local economic characteristics that may affect the quality of the broadband infrastructure available to the sampled firms. The results show that the impact of broadband Internet on labor productivity is reduced and, related to the high variability evidenced in the previous estimates, it is not significant at the 10 percent level. Therefore, broadband Internet use does not seem to have an impact in the observed early phase of broadband diffusion.

The econometric analysis now turns to the analysis of process innovations. Table 5.6 presents the index coefficient results from the estimation of the likelihood of firms to perform process innovation. Column (1) estimates a Probit model. We can observe a positive and significant impact of broadband Internet use on process innovations.[38] This result is not surprising, as broadband Internet offers firms new possibilities to reorganize and facilitate their processes (e.g., more efficiency in the communication between differently located units or faster information gathering).

However, it is possible that firms' innovation success is reversely related to the use of broadband Internet. In particular, more innovative firms may be more likely to use innovative technologies, such as broadband Internet. To ensure consistent estimations, tackling possible endogeneity, columns (2)-(5) estimate a recursive bivariate Probit model that uses Internet availability as an instrument.[39] In particular, analogous to the previously described productivity estimation, the specification presented in column (2) estimates the impact of broadband Internet on process innovations, controlling for input factors and additional controls (economic activity, location and export activity). It shows a positive and highly significant impact of broadband Internet use.

Columns (3)-(5) take into account additional controls relevant for the estimation of success in innovations. Column (3) adds a control for firms' innovative experience by introducing a control for a firm's success in previous periods product innovations.[40] The impact of firms' innovative experience is, as expected, positive and significant. The effect, however, does not change the positive and significant impact of broadband Internet. Column (4) adds ICT intensity (i.e., percentage of employees working mainly with a PC) to ensure that Internet broadband does not only reflect an effect driven by the high likelihood of broadband Internet using firms to use ICT in general intense. However, even though

[38] As the result yields an index coefficient, the size of the impact is not identifiable in this step. Marginal effects are provided in the next table.

[39] The likelihood ratio test holds in all specifications such that we suppose that there is endogeneity. Therefore the recursive bivariate Probit is preferable as the common Probit does not yield consistent estimates.

[40] The 2002 ZEW ICT Survey (ZEW 2002) did not ask for process innovations, such that product innovations are used as a proxy.

the ICT intensity is significant, the impact of Internet broadband remains positive and significant. Column (5) considers the impact of a heterogeneous labor force. It explicitly controls for whether the percentage of highly qualified employees has an impact on the success in process innovations, which is not the case. Still, the impact of broadband Internet remains highly significant and positive.

In order to summarize and to quantify the effects, table 5.7 presents the marginal effects for the Probit and the conditional marginal effects for the bivariate Probit at the mean given that firms successfully do product innovations and use broadband Internet. Column (1) shows the Probit baseline estimation. Broadband Internet use has an impact of 7.96 percentage points on the probability to innovate. Column (2) provides the first recursive bivariate Probit's marginal effects estimation yielding a severe increase to 63.00 percentage points in the probability to innovate at the mean of all variables and broadband Internet being used. Column (3) adds past product innovation as an additional explanatory variable, which has an impact of 9.50 percentage points. Including this variable in the estimation, the impact of broadband use decreases to still considerable 62.57 percentage points. Column (4) includes ICT intensity, which has no own significant effect on the probability of process innovations. However, the impact of broadband use on the probability of successful process innovation decreases to 56.60 percentage points. Column (5) controls for high skilled labor, with high skilled labor not being significant and the marginal effect of broadband Internet remaining very high (56.01 percentage points).

Instead of observing the marginal effects at the mean for the Probit and the conditional marginal effects for the recursive bivariate Probit, table 5.8 presents the average marginal effect for Probit and the "average causal effect"(Angrist and Pischke 2009, p. 200) for the recursive bivariate Probit model which provides effects that capture the impact on both kinds of firms: broadband Internet using and not using firms. In column (1), the average marginal effect of broadband Internet use in the Probit model is shown. On average, broadband Internet use increases in the Probit model the probability of process innovation by 7.80 percentage points, which is close to the effect at the mean. Column (2) investigates the "average causal effect"(Angrist and Pischke 2009, p. 200) in the recursive bivariate Probit estimation, which has a size of 45.30 percentage points on the probability of process innovation. Controlling for past innovations, ICT intensity and the employees' qualification leads to an decreasing size of the effects (from 44.70 to 40.57 percentage points). The common Probit model seems to underestimate the effect of broadband Internet use. The increase is presumably caused by the previously described endogenous relationship. This rather larger increase may also be partially explained by an increase of imprecision of the explanatory variables (i.e., broadband use) as using instruments leads to increased standard errors. Moreover, estimations may suffer from a small data size. In particular, data size reaches a critical minimum, just sufficient for proper identification.[41] Even though the exact quantification of the impact level of the use of broadband Internet on process innovations remains difficult due to the mentioned sources of imprecision, the rather large and strong impact implies that broadband Internet diffusion led to a wide spread of reorganization and restructuring of business processes among firms.

Analogous to the effect of broadband use on process innovation, table 5.9 analyzes the effect of broadband Internet on product innovations.[42] Column (1) estimates a baseline Probit estimation. This shows a significant positive correlation between broadband use and product innovation, as it was the case for process innovations. Columns (2)-(5) consider, again, possible endogeneity and estimate a recursive bivariate Probit model, adding further controls in order to take into account other sources of variation.[43] Column (2) adds controls for firms' inputs. A positive and highly significant impact of broadband Internet on product innovation is derived. Column (3) adds past product innovation, which are positive and highly significant. The impact of broadband Internet remains positive and significant. Column (4) controls for general ICT intensity, its impact, however, is not significant, while the impact of broadband use remains positive and significant. Finally, column (5) disentangles the qualification of the workforce and can reveal a positive and significant impact of the proportion of highly qualified employees on the probability to have product innovations, without changing the highly significant and positive impact of broadband Internet on product innovations.

Table 5.10 provides estimates for the marginal effects for the product innovation case, analogous to the analysis of process innovations. Column (1), summarizing the marginal effects of the baseline Probit estimation, shows that the effect of broadband has an average effect of 6.93 percentage points on the probability of successful product innovation. The first recursive bivariate Probit specification is provided in column (2). Broadband Internet use has an overall effect of 35.71 percentage points. In addition, the size of the labor force has an impact of 6.68 percentage points and the exporting behavior an impact of 16.85 percentage points. Controlling for past innovations in column (3), the marginal

[41] Park (2009, p. 57) states that for proper estimation of the bivariate Probit referring to the rule of thumb by Long (1997) for Maximum Likelihood estimation in general, "500 observations and at least additional 10 per independent variable are required"(Park 2009, p. 57). For our estimations, this means approximately a minimum of 850 observations, which we just have.

[42] According to the analysis of process innovations, we first present the index coefficients and provide the marginal effects later on.

[43] The likelihood ratio test holds in the two richer specifications such that we suppose that there is endogeneity. Therefore the recursive bivariate Probit is preferable as the common Probit does not yield consistent estimates.

effect on the probability to have product innovations is 36.40 percentage points. The impact of the size of the labor force decreases to 4.76 percentage points and the impact of exporting to 11.70 percentage points. The effect of broadband Internet increases to 41.68 percentage points. Column (4) adds the ICT intensity, which explains an impact of 10.18 percentage points on innovation, but is not significant. Introducing this control does not lead to diminishing significance of the previous significant results (The impact of broadband increases to 47.76 percentage points). Including the qualification structure as an explanatory variable in column (5) shows an marginal effect of 27.41 percentage points on product innovations. The coefficient of broadband Internet use, remains nearly unchanged.

Table 5.11 analyzes the "average causal effect"(Angrist and Pischke 2009, p. 200) of broadband use on the probability of innovation. While column (1) shows the rather low estimates of the Probit (6.26 percentage points), column (2) provides the estimates of the first bivariate Probit specification. The estimate yields an impact of 28.29 percentage points. Introducing all controls in all specifications, it hardly changes and becomes 34.58 percentage points in the final specification. The same finding as in the process innovation part applies. The common Probit model seems to underestimate the effect of broadband Internet use. This may be induced by the endogenous relationship between broadband Internet use and innovational success. The recursive bivariate Probit model tackles this problem. There is still imprecision in the estimates requiring a careful interpretation of the size of the coefficients. This imprecision is caused by the same sources as in the process innovation estimates. First, instrumenting leads to a large increase in standard errors and second, data size is critical, just sufficient for a consistent estimation. The large size, however, indicates that broadband Internet changed massively the way and the kind of offered products and services. The introduction of broadband Internet and its fast pace of diffusion implies that this presumably had a significant impact on the overall economy and allowed firms to successfully offer new products and services or at least to improve those significantly.

5.6 Conclusions

The chapter has analyzed the impact of broadband Internet use on firms' performance. Instrumental variable estimations revealed different results for the analysis of productivity and for innovation. The analysis found correlations that have shown a very heterogeneous impact on labor productivity. This impact, however, is not robust and statistically not different from zero. In contrast to the productivity findings, the impact of broadband Internet use on success in innovations (process and product innovations) is strong, robust and can be viewed to be causal.

These findings support the hypothesis that broadband Internet leads to changes in the business processes leading into severe offering of new products and services or at least in a significant improvement of those. The fact that the impact on labor productivity is not significant suggests that this massive change is accompanied by a process of learning, which is typical for the introduction of a GPT (Draca et al. 2007, pp. 105-106). These effects on the productivity, however, will presumably arise in the long run, after learning took place and firms know how to take advantage of the benefits of broadband Internet. How exactly firms translate the new possibilities to improve their productivity offered by broadband Internet remains an open question for further research.

5.7 Appendix

Table 5.1: Summary Statistics

Variable	Mean	Std. Dev.	Observations
Labor Productivity 2003	0.19	0.24	1437
Process Innovation 2003 - 2001	0.75	0.43	1789
Product Innovation 2003 - 2001	0.65	0.48	1783
Broadband Internet Use 2002	0.61	0.49	3901
Total Employees 2001	166.11	260.80	4037
Investment 2001 (in Millions)	1.95	6.25	2594
% of Employees using a PC	0.52	0.34	4030
% of High Qualified Employees	0.21	0.25	3871
Product Innovation 2001 -1999	0.65	0.48	3997
Enterprise Resource Planing	0.77	0.42	4012
Supply Chain Management	0.22	0.41	3993
Exporting Behavior	0.53	0.50	4000
Eastern Germany	0.21	0.41	4036

Source: The sample contains 4,400 observations per ZEW ICT survey 2002 and 2004 (ZEW 2002, ZEW 2004).

Table 5.2: Postal Code Regions with DSL Availability

Postal Code Regions with DSL Availability			
Year	Number	Percentage	Cumulative Percentage
2000	1249	21.73	21.73
2001	3094	53.84	75.57
2002	625	10.88	86.45
2003	69	1.2	87.65
2004	277	4.82	92.47
2005	200	3.48	95.95
2006	125	2.18	98.12
2007	80	1.39	99.51
2008 & 2009	28	0.48	100

Mean values. A postal code region has broadband availability
if at least one main distribution frame in the area
is equipped with DSL. Source: Data from Deutsche Telekom AG
(Deutsche Telekom 2009).

Table 5.3: DSL Availability measured in Number of Days

	Mean	25%	50%	75%	90%
Days of DSL Availability	332	180	328	458	607

Reading help: On average, firms are located
in postal code areas where DSL is available for 332 days.
Source: Data from Deutsche Telekom AG (Deutsche Telekom 2009). Estimation Sample.

Table 5.4: Descriptive Statistics, Full Sample

Variable	**Mean**	**with broadband**	**without broadband**	**Number of obs.**
Total Sales 2001	79.08	116.15	18.98	3013
	(1234.74)	(1602.83)	(62.31)	
Total Employees 2001	166.11	205.46	94.90	4037
	(260.80)	(290.45)	(176.29)	
% of Employees using a Comp.	0.52	0.59	0.40	4030
	(0.34)	(0.33)	(0.32)	
Internet Use 2002	0.98	1.0	0.95	4030
	(0.14)	(0.0)	(0.23)	
Labor Productivity 2003	0.19	0.20	0.18	1437
	(0.24)	(0.26)	(0.21)	
Product Innovation 2001 - 2003	0.65	0.71	0.57	1783
	(0.48)	(0.46)	(0.50)	
Process Innovation 2001 - 2003	0.75	0.80	0.68	1789
	(0.43)	(0.40)	(0.47)	

Source: ZEW ICT survey 2002 and 2004 (ZEW 2002, ZEW 2004).
Standard errors in brackets.

Table 5.5: Results for Labor Productivity; OLS and IV

Labor Productivity	***OLS***			***IV GMM***		
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband Use in 2002	0.1127**	0.7997*	0.6576	0.7037*	0.6899*	0.3430
	(0.0456)	(0.4360)	(0.4139)	(0.4165)	(0.4122)	(0.3700)
Employees (in logs)	-0.1571***	-0.2854***	-0.2596***	-0.2514***	-0.2623***	-0.2531***
	(0.0279)	(0.0817)	(0.0801)	(0.0801)	(0.0772)	(0.0736)
Investment (in logs)	0.1511***	0.2247***	0.2130***	0.2060***	0.2112***	0.2226***
	(0.0201)	(0.0819)	(0.0757)	(0.0758)	(0.0732)	(0.0706)
% of Employees using			0.4902***	0.5398***	0.5258***	0.6091***
a Computer			(0.1874)	(0.1889)	(0.1806)	(0.1586)
Enterprise Resource Planning					-0.0497	0.0064
					(0.0886)	(0.0828)
Supply Chain Management					0.1160	0.1383**
					(0.0728)	(0.0680)
% of High Qualified Employees				-0.1660	-0.1745	-0.1139
				(0.1387)	(0.1377)	(0.1329)
Product Innovation (1999-2001)				-0.0843	-0.0870	-0.0908
				(0.0695)	(0.0700)	(0.0656)
GDP per Capita						-0.0012
						(0.0019)
Postal Code Dummies						x
Export Dummy	0.1666***	0.0475	0.0426	0.0603	0.0498	0.0583
	(0.0526)	(0.0815)	(0.0755)	(0.0797)	(0.0800)	(0.0755)
Constant	-1.3465***	-1.0650**	-1.2632***	-1.2852***	-1.1838**	-1.1063**
	(0.1519)	(0.5244)	(0.4702)	(0.4741)	(0.4605)	(0.4654)
Broadband Use, first stage						
Years of DSL availability		0.2396***	0.1917**	0.1941**	0.1863**	0.1966**
		(0.0788)	(0.0803)	(0.0809)	(0.0814)	(0.0854)
Employees (in logs)		0.1928***	0.2156***	0.2176***	0.1843***	0.1745***
		(0.0459)	(0.0468)	(0.0476)	(0.0487)	(0.0495)
Investment (in logs)		0.0602*	0.0451	0.0455	0.0397	0.0414*
		(0.0312)	(0.0319)	(0.0322)	(0.0326)	(0.0331)
% of Employees using			1.1162***	1.1035***	1.044***	1.0031***
a Computer			(0.1590)	(0.1696)	(0.1713)	(0.1744)
Enterprise Resource Planning					0.3135***	0.3585***
					(0.1073)	(0.1101)
Supply Chain Management					0.1482	0.1508
					(0.1146)	(0.1158)
% of High Qualified Employees				0.0014	-0.0071	0.0500
				(0.2316)	(0.2320)	(0.2479)
Product Innovation (1999-2001)				-0.0410	-0.0702	-0.0685
				(0.0994)	(0.1004)	(0.1025)
GDP per Capita						0.0014
						(0.0036)
Postal Code Dummies						x
Export Dummy		0.2203**	0.1676*	0.1843*	0.1755*	0.1213
		(0.0982)	(0.1000)	(0.1020)	(0.1027)	(0.1054)
Constant		-1.0705***	-1.4635***	-1.4546***	-1.5777***	-1.6129***
		(0.2620)	(0.2735)	(0.2761)	(0.2846)	(0.3313)
Number of Observations	1137	770	770	759	752	751
Wald test		0.00	0.00	0.00	0.00	0.00
R^2	0.2101	0.0268	0.1232	0.1049	0.1041	0.2392

Robust Standard errors are in brackets. The table only shows the first stage for broadband use and not for the inputs. All estimations include controls for industries and location.
Significant at 1% ***, significant at 5% ** , significant at 10% *

Table 5.6: Results for Process Innovation, Probit and bivariate Probit

Process Innovation 2003-2001	***Probit*** (1)	***Recursive Bivariate Probit*** (2)	(3)	(4)	(5)
Broadband Use in 2002	0.2599***	1.4082***	1.3985***	1.2976***	1.2878***
	(0.0931)	(0.1792)	(0.1823)	(0.2340)	(0.2389)
Employees (in logs)		-0.0461	-0.0615	-0.0594	-0.0589
		(0.0481)	(0.0482)	(0.0513)	(0.0516)
Investment (in logs)		0.0720**	0.0684**	0.0781**	0.0785**
		(0.0324)	(0.0323)	(0.0330)	(0.0330)
Product Innovation (1999-2001)			0.2541**	0.3053***	0.3022***
			(0.0997)	(0.1006)	(0.1008)
% of Employees using a Comp.				-0.3166	-0.3458*
				(0.1974)	(0.2025)
% of High Qualified Employees					0.1693
					(0.2306)
Exports	0.2700***	0.0363	-0.0103	0.0116	0.0068
	(0.1017)	(0.0995)	(0.1003)	(0.1022)	(0.1025)
GDP per Capita		-0.0039	-0.0030	-0.0021	-0.0022
		(0.0033)	(0.0034)	(0.0034)	(0.0034)
Postal Code Dummies		x	x	x	x
Constant	0.5523***	0.3850	0.2970	0.3875	0.3967
	(0.1689)	(0.3066)	(0.3084)	(0.3143)	(0.3152)
Broadband Use					
Years of DSL Availability		0.2791***	0.2654***	0.2415***	0.2415***
		(0.0727)	(0.0734)	(0.0764)	(0.0766)
Employees (in logs)		0.1796***	0.1732***	0.2026***	0.2025***
		(0.0470)	(0.0473)	(0.0483)	(0.0484)
Investment (in logs)		0.0562*	0.0565*	0.0483	0.0485
		(0.0325)	(0.0324)	(0.0331)	(0.0331)
Product Innovation (1999-2001)			0.0883	-0.0202	-0.0194
			(0.0979)	(0.1012)	(0.1014)
% of Employees using a Comp.				1.0549***	1.0632***
				(0.1643)	(0.1728)
% of High Qualified Employees					-0.0374
					(0.2382)
Exports		0.1804*	0.1610	0.1335	0.1348
		(0.1002)	(0.1021)	(0.1040)	(0.1045)
GDP per Capita		0.0034	0.0037	0.0012	0.0012
		(0.0035)	(0.0035)	(0.0036)	(0.0036)
Postal Code Dummies		x	x	x	x
Constant		-1.1047***	-1.1001***	-0.9558***	-0.9425***
		(0.2935)	(0.2935)	(0.3009)	(0.3020)
Number of Observations	985	985	985	985	985
Likelihood Ratio Test		0.0033	0.0042	0.0128	0.0145

Standard errors are in brackets. All estimations include controls for industries and location.
Significant at 1% ***, significant at 5% ** , significant at 10% *

Table 5.7: Marginal Effects Process Innovation

Process Innovation 2003-2001	***Probit***	***Recursive Bivariate Probit***			
	(1)	(2)	(3)	(4)	(5)
Broadband Use in 2002	0.0796***	0.6300***	0.6257***	0.5660***	0.5601***
	(0.0288)	(0.1045)	(0.1066)	(0.1336)	(0.1361)
Employees (in logs)		0.0064	0.0008	0.0039	0.0039
		(0.0134)	(0.0134)	(0.0141)	(0.0142)
Investment (in logs)		0.0291***	0.0279***	0.0295***	0.0296***
		(0.0091)	(0.0090)	(0.0092)	(0.0092)
Product Innovation (1999-2001)			0.0950***	0.0971***	0.0960***
			(0.0303)	(0.0308)	(0.0308)
% of Employees using a Comp.				0.0180	0.0093
				(0.0521)	(0.0532)
% of High Qualified Employees					0.0483
					(0.0663)
GDP per Capita		-0.0008	-0.0005	-0.0005	-0.0006
		(0.0009)	(0.0010)	(0.0010)	(0.0010)
Export Dummy	0.0819***	0.0327	0.0155	0.0184	0.01670
	(0.0309)	(0.0279)	(0.0280)	(0.0289)	(0.0289)
Number of Observations	985	985	985	985	985

Marginal effects at the mean in column (1). Marginal effects at the mean, conditional on broadband being used in columns (2)-(5), except of coefficient for broadband use. Standard errors in brackets. Significant at 1% ***, significant at 5% ** , significant at 10% *

Table 5.8: Average Marginal Effects of Broadband Use, Process Innovation

Process Innovation 2003-2001	***Probit*** (1)	***Recursive Bivariate Probit*** (2)	(3)	(4)	(5)
Broadband Use in 2002	0.0780***	0.4530***	0.4470***	0.4093***	0.4057***
	(0.0254)	(0.0687)	(0.0688)	(0.0788)	(0.0807)
Number of Observations	985	985	985	985	985

Column (1) provides average marginal effects. Columns (2)-(5)
provide “average causal effects”(Angrist and Pischke 2009, p. 200). Standard errors in brackets.
Significant at 1% ***, significant at 5% ** , significant at 10% *

Table 5.9: Results for Product Innovation, Probit and bivariate Probit

Product Innovation 2003-2001	***Probit*** (1)	***Recursive Bivariate Probit*** (2)	(3)	(4)	(5)
Broadband Use in 2002	0.1893**	0.8529*	0.9717**	1.0862***	1.1048***
	(0.0891)	(0.4435)	(0.4913)	(0.3867)	(0.3901)
Employees (in logs)		0.1221*	0.0638	0.0500	0.0467
		(0.0671)	(0.0702)	(0.0660)	(0.0670)
Investment (in logs)		0.0175	0.0007	-0.0010	-0.0007
		(0.0332)	(0.0334)	(0.0322)	(0.0324)
Product Innovation (1999-2001)			0.8624***	0.8450***	0.8291***
			(0.1668)	(0.1380)	(0.1392)
% of Employees using a Comp.				-0.1544	-0.2997
				(0.2438)	(0.2416)
% of High Qualified Employees					0.6728***
					(0.2548)
Export Dummy	0.5763***	0.3923***	0.2370*	0.2272**	0.2004*
	(0.0982)	(0.1227)	(0.1233)	(0.1143)	(0.1145)
GDP per Capita		-0.0028	0.0000	0.0003	-0.0001
		(0.0034)	(0.0036)	(0.0035)	(0.0035)
Postal Code Dummies		x	x	x	x
Constant	-0.1097	-1.0635***	-1.4653***	-1.4139***	-1.3794***
	(0.1570)	(0.3095)	(0.3426)	(0.3494)	(0.3532)
Broadband Use					
Years of DSL Availability		0.2426***	0.2249***	0.1987**	0.1954**
		(0.0799)	(0.0796)	(0.0792)	(0.0793)
Employees (in logs)		0.1848***	0.1755***	0.2015***	0.2009***
		(0.0474)	(0.0482)	(0.0489)	(0.0490)
Investment (in logs)		0.0600*	0.0602*	0.0515	0.0525
		(0.0323)	(0.0324)	(0.0330)	(0.0331)
Product Innovation (1999-2001)			0.0979	-0.0019	-0.0022
			(0.0992)	(0.1021)	(0.1023)
% of Employees using a Comp.				1.0950***	1.0910***
				(0.1646)	(0.1726)
% of High Qualified Employees					0.0155
					(0.2348)
Exports		0.1648	0.1438	0.1037	0.1009
		(0.1016)	(0.1037)	(0.1049)	(0.1056)
GDP per Capita		0.0029	0.0031	0.0004	0.0004
		(0.0035)	(0.0035)	(0.0036)	(0.0036)
Postal Code Dummies		x	x	x	x
Constant		-0.5671	-0.6986	-0.8494**	-0.8697**
		(0.3645)	(0.4606)	(0.4254)	(0.4413)
Number of Observations	985	985	985	985	985
Likelihood Ratio Test		0.1676	0.1967	0.0871	0.0927

Standard errors in brackets. All estimations include controls for industries and location.
Significant at 1% ***, significant at 5% ** , significant at 10% *

Table 5.10: Marginal Effects Product Innovation

Product Innovation 2003-2001	***Probit*** (1)	***Recursive Bivariate Probit*** (2)	(3)	(4)	(5)
Broadband Use in 2002	0.0693**	0.3571*	0.4168*	0.4776**	0.4873**
	(0.0327)	(0.2074)	(0.2392)	(0.1942)	(0.1977)
Employees (in logs)		0.0668***	0.0476**	0.0505**	0.0492**
		(0.0180)	(0.0194)	(0.0199)	(0.0203)
Investment (in logs)		0.0132	0.0080	0.0073	0.0076
		(0.0115)	(0.0118)	(0.0121)	(0.0119)
Product Innovation (1999-2001)			0.3640***	0.3562***	0.3496***
			(0.0372)	(0.0375)	(0.0379)
% of Employees using a Comp.				0.1018	0.0439
				(0.0662)	(0.0686)
% of High Qualified Employees					0.2741***
					(0.0933)
GDP per Capita		-0.0008	0.0004	0.0002	0.0000
		(0.0013)	(0.0013)	(0.0013)	(0.0013)
Export Dummy	0.2091***	0.1685***	0.1170***	0.1080***	0.0966**
	(0.0350)	(0.0371)	(0.0394)	(0.0397)	(0.0401)
Number of Observations	985	985	985	985	985

Marginal effects at the mean in column (1). Marginal effects at the mean, conditional on broadband being used in columns (2)-(5), except of coefficient for broadband use. Standard errors in brackets. Significant at 1% ***, significant at 5% ** , significant at 10% *

Table 5.11: Average Marginal Effects of Broadband Use, Product Innovation

Product Innovation 2003-2001	***Probit*** (1)	***Recursive Bivariate Probit*** (2)	(3)	(4)	(5)
Broadband Use in 2002	0.0626***	0.2829***	0.3024**	0.3425***	0.3458***
	(0.0284)	(0.0944)	(0.1220)	(0.1110)	(0.1168)
Number of Observations	985	985	985	985	985

Column (1) provides average marginal effects. Columns (2)-(5)
"average causal effects"(Angrist and Pischke 2009, p. 200). Standard errors in brackets.
Significant at 1% ***, significant at 5% ** , significant at 10%*

6 Conclusions

This thesis has dealt with various aspects of *competition and innovation.* I briefly summarise the main results.

Chapter 2, *Cartel Destabilization and Leniency Programs - Empirical Evidence*, uses a different approach than the literature to evaluate efficiency of leniency programs. The results back the programs implemented in the OECD claiming their efficiency. The approach is confronted with some potential drawbacks, however, it can solve several problems, other studies have due to their focus on detected cartels only (Brenner 2009, Miller 2009) and reveals a presumably causal impact. The study, as discussed in chapter 2, therefore, as it captures the impact on detected and deterred cartels and adds new evidence to already existing literature.

Chapter 3, entitled *Endogenous Firm Heterogeneity, ICT and R&D Incentives*, provides an empirical analysis, first, on the impact of information and communication technologies (ICT) on the heterogeneity in firm productivity in industries and, second, on the impact of this heterogeneity on firm strategies regarding R&D. It relates on the existing literature uncovering differences in the productivity distribution and tries to provide evidence of the impact on a firm level, which has previously found on an industry level (Chun et al. 2008). This impact, which characterizes competition in the market, can be shown to exist on a firm level, however, depending on the current use of ICT. In particular, as shown and discussed in chapter 3, specific ICT applications have to be used in an ICT intense firm environment to generate this heterogeneity. In a second step, the chapter proposes a positive impact on R&D incentives.

Chapter 4, *How Market Regulation Affects Network and Service Quality in Related Markets*, investigates the relationship between regulation and incentives for investments into quality and adds new evidence to the large literature on it. The main aspect is the analysis on complementary markets, of which we consider access and service markets, in particular broadband Internet and Internet services. In contrast to most of the existing literature, we show that adding a concept of perceived quality, regulation can have a positive impact on overall quality provided jointly in access and service markets. However, depending on the importance of both markets quality regulation can also have negative effects on the quality provided in both markets. We first apply the analysis in an environment where the complementarity requires joint consumption for utility generation and then relax the assumptions using a model that still has a complementarity, but not requiring joint consumption strictly, which shows the that the general results hold.

Chapter 5, *An Empirical Analysis of Internet Broadband Use and Firm Success*, analyzed how broadband Internet use, which is denoted to have GPT characteristics (Holt and Jamison 2009, p. 575; Czernich et al., 2009 pp. 1-2) affects firms' productivity and output in innovations. As discussed in chapter 5 one can observe correlations for both productivity and innovation, but instrumental variable estimations reveal causality in process and product innovations, but not for productivity. This leaves a puzzling picture, however indicating a change in how firms' organize themselves and how they offer new products. As discussed in chapter 5, we cannot proof an increase in productivity, however, it is still possible that new firm organization and products may increase efficiency in the long run (See, for the argumentation regarding GPT, Draca et al. 2007, pp. 105-106).

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