ZEW Economic Studies

Bettina Peters

Vol. 38

Innovation and Firm Performance

An Empirical Investigation for German Firms

ZEW
Zentrum für Europäische Wirtschaftsforschung GmbH

Physica-Verlag
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Publication Series of the Centre for European Economic Research (ZEW), Mannheim, Germany

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Zugl.: Würzburg, Univ., Diss., 2006

ISBN 978-3-7908-2025-6 e-ISBN 978-3-7908-2026-3

DOI 10.1007/978-3-7908-2026-3

Library of Congress Control Number: 2007941521

Production: LE-TEX Jelonek, Schmidt & Vöckler GbR, Leipzig
Cover-design: WMX Design GmbH, Heidelberg

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

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To my family.

Preface

The term innovation generally means 'something new' – and this monograph is an innovation in a sense that it provides the reader with some new insights into the consequences of innovation activities at the firm level. In recent years, the importance of innovations for improving competitiveness and stimulating economic growth has increasingly become the focus of public attention. The Federal Government, for instance, proclaimed 2004 as the 'year of innovation' and started several initiatives to foster innovation activities in Germany. This monograph is aimed at the empirical assessment of the impact of the introduction of new products and processes on various firm performance measures using modern microeconometric techniques.

This book represents the written part of my doctoral examinations at the Department of Economics at the University of Würzburg which were concluded with the oral examinations on July 28, 2006. The completion of this thesis was only possible with the assistance and the promotion of numerous individuals and institutions. First of all, I want to express my gratitude to my supervisor Martin Kukuk for supporting my academic research. During all the time he put his trust in me and gave me sufficient freedom to realise my ideas. I would like to thank him and Prof. Dr. Norbert Schulz, who kindly accepted to take on the second report, for their critical comments and constructive suggestions.

In addition, I am indebted to the Centre for European Economic Research (ZEW) and, in particular, to Wolfgang Franz and Georg Licht for providing me with excellent and stimulating working and research conditions. I really appreciate Georg's unswerving support and inspiring comments. I would also like to thank Thomas Kohl, all administrative staff, and, in particular, Heidi Halder and Heidrun Förster for their support making the everyday work life at the ZEW much easier as well as more productive.

This work has been made possible through different research projects carried out at the ZEW. In particular, Chapter 3 of this book originates from the research project *Innovation and Employment in European Firms: Microeconometric Evidence (IEEF)* financed by the European Commission within

the Fifth Framework Programme (Project No. SERD-2000-00110). I am especially grateful to my co-authors Jordi Jaumandreu, Jacques Mairesse, and Rupert Harrison for their cooperation, precious ideas, many fruitful discussions and, of course, for organising meetings in Madrid, Paris, and London. The research has also considerably benefitted from joint work with the rest of the IEEF team consisting of Laura Abramovsky, Rachel Griffith, Elena Huergo, Norbert Janz, Elizabeth Kremp, Alberto Lopez, Pierre Mohnen, Tobias Schmidt, Helen Simpson, and Bronwyn Hall (inofficial member). It was a real pleasure for me to work with all of them.

Special thanks go to Ulrich Kaiser – for constructive comments but also for continuously asking me about the progress of my thesis, and for encouraging me to finish it – and to François Laisney. I appreciate his valuable econometric courses at the ZEW as well as the patience he exercised and effort he spent every time I sought econometric advice. Helpful econometric comments and proposals that significantly improved different parts of this study were also put forward by Winfried Pohlmeier and Jeffrey Wooldridge, and are highly appreciated.

I would also like to thank my friends and (present and former) colleagues at the ZEW for the inspiring working environment. In addition to Norbert Janz, I have particularly gained from comments by and discussions with Christian Rammer and Wolfgang Sofka. I am also grateful to Birgit Aschhoff, Patrick Beschorner, Katrin Cremers, Dirk Czarnitzki, Jürgen Egeln, Helmut Fryges, Diana Heger, Oliver Heneric, Katrin Hussinger, and Tobias Schmidt for their help and encouragement.

Data availability and quality largely determine the success of empirical research. This research would not have been possible without the data from the Mannheim Innovation Panel. I am, therefore, grateful to all firms which devote their time to thoroughly fill out the questionnaires. Furthermore, I owe our programmer Thorsten Doherr and all our student assistants ('MIP-Hiwis') a great debt of gratitude for their careful data collection and preparation. I would also like to thank Andrew Flower, Alexis Develle, and Tyler Schaffner for excellent proofreading.

Most importantly, I thank God. I am further deeply grateful to all my friends for their patience, heartening words and prayers over the past six years. Finally, as a sign of my gratitude for their permanent and unconditional support, I wish to dedicate this work to my family and, particularly, to my mother and to the memory of my father.

Mannheim, August 2007 *Bettina Peters*

Contents

1

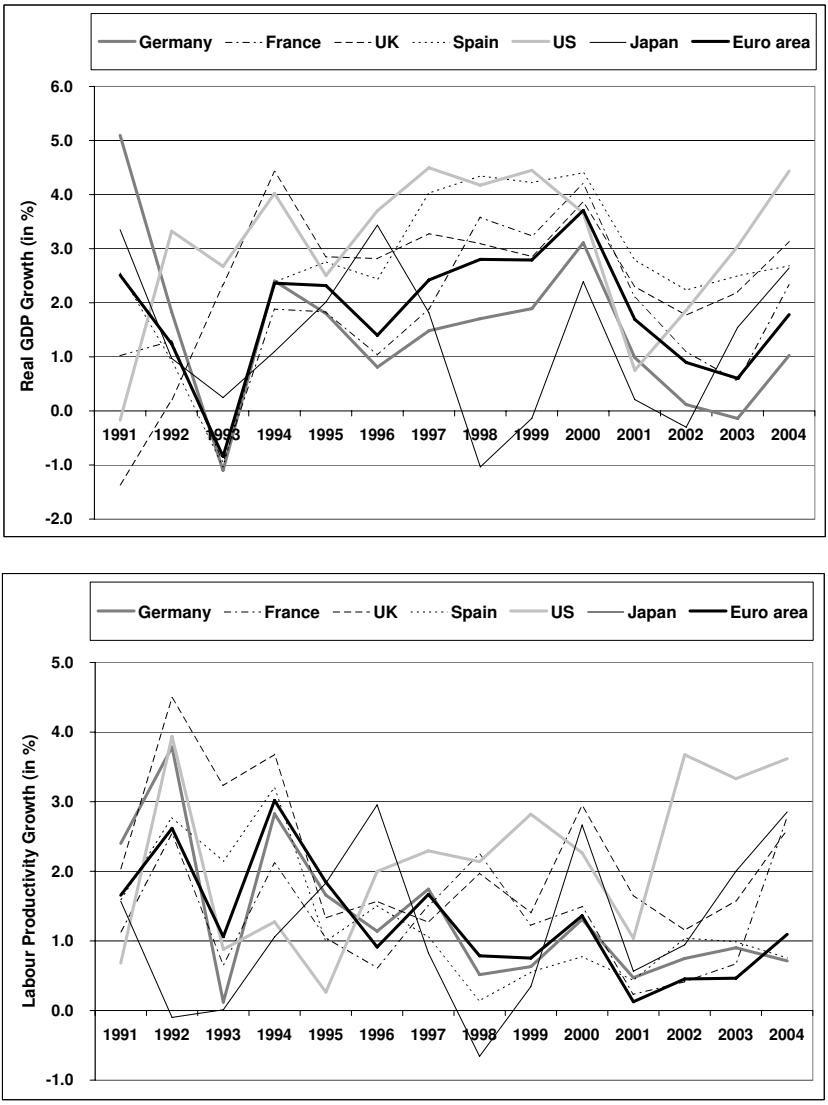
Introduction

1.1 Motivation

Currently, one of the German economy's main problems is its weak growth performance, which shows up in low growth rates for potential output and for real gross domestic product (GDP) (Sachverständigenrat, 2005). Comparing important economic performance indicators within the EU15 countries, it further becomes apparent that economic development in Germany has lagged behind that of many other European countries since the mid 1990s. For instance, since 1995 Germany has continuously been among the group of the three countries reporting the lowest growth rates in real GDP. Similarly, the average growth rate of labour productivity of about one percent for the period 1995-2004 ranks within the lower third of the EU15 countries. In addition to falling behind other competitors in Europe, Germany – and also Europe as a whole – have been unable to keep pace with the economic development in terms of real GDP growth or labour productivity growth in the US, as can be seen in Fig. 1.1. Fig. 1.2 further shows that the low growth development is accompanied by a steady rise in the rate of unemployment over the last 15 years in Germany, whereas other countries, e.g., the United Kingdom (UK) or Spain, have experienced great success in reducing unemployment. In 2004, the internationally harmonised unemployment rate amounts to 10% in Germany. This is one percentage point above the European average, 4 percentage points higher than in the US and even twice as high as in Japan or the UK (see OECD, 2005a). Furthermore, looking at a longer period of time, it turns out that each business cycle has been accompanied by a rise of the base rate of unemployment in Germany. This phenomenon has not been observed, for instance, in the US (see Sachverständigenrat).

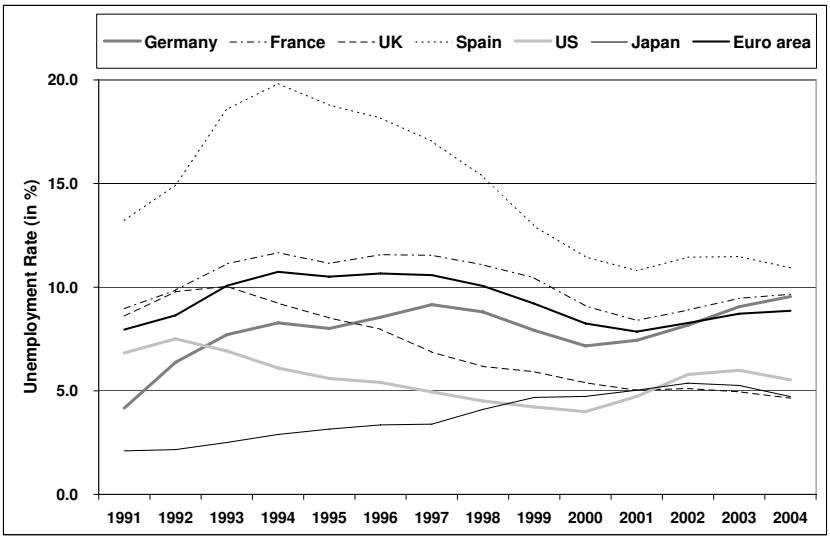
Since productivity and employment are key to micro- and macroeconomic wealth, the poor performance relative to other European countries and in particular to the US has been an important focus for government policy in Germany and has induced widespread reforms aimed at increasing growth and lowering unemployment. The weak productivity and employment perfor-

Fig. 1.1: Real GDP Growth Rate and Labour Productivity Growth Rate in Selected OECD Countries, 1991-2004



Notes: The Euro area denotes the EU15 countries. Labour Productivity: Real output per employed person in the business sector. Business sector employment is defined as total economy employment less public sector employment. Business output is defined as real GDP less the government real wage bill less net real indirect taxes less real consumption of fixed capital. Thus, business output is valued at factor costs. Source: OECD (2005a); own representation.

Fig. 1.2: Standardised Unemployment Rate in Selected OECD Countries, 1991-2004



Notes: The standardised unemployment rate is defined as the number of unemployed persons as a percentage of the civilian labour force, where unemployed persons are defined as those who report that they are without work, that they are available for work, and that they have taken active steps to find work in the last 4 weeks (according to ILO guidelines). For Germany, the standardised unemployment rate prior to 1993 refers to West Germany.
Source: OECD (2005a); own representation.

mance is likely to have originated from a set of sources. Institutional conditions on the labour market, high indirect labour costs, a high corporate taxation, but also problems of adjustment due to German reunification are most often mentioned. Another cause, which is likewise adduced in the public debate and which is given a high significance, is that German and, more generally, European enterprises lack innovative ability. The economic relevance of this shortfall is that innovation is widely considered to be a key long-term driving force for competitiveness and growth of enterprises as well as national economies as a whole. For instance, the Sapir report, written on the initiative of the European Commission, argued that Europe's weakness is mainly a symptom of its failure to transform into an innovation-based economy. In the first three post-war decades, Europe mainly grew through adopting and incrementally updating US innovations. But now, Europe is closer to the technology frontier and must grow through innovations rather than imitations (see Sapir et al., 2003; and for a theoretical exploration, Acemoglu, Aghion, and Zilibotti, 2006). Against the background of this discussion, the Federal

Government proclaimed 2004 as the "year of innovation" and started several initiatives to foster innovation activities in Germany.[1]

A lack of innovative ability can find expression in different stages of the innovation process, giving rise to the following questions: (i) Do prevailing circumstances exist which impede or prevent innovation activities within firms? For instance, firms can be forced to refrain from innovating due to amiss venture capital or, more generally, due to financial constraints, a shortage of high-skilled personnel, legal regulations etc.[2] (ii) In view of the fact that investments in research and experimental development (R&D) reach high levels in a world-wide comparison,[3] a natural question is whether German firms are internationally not competitive in translating their R&D investments into new products and production technologies? (iii) Finally, are innovators not able to translate their innovation outcomes into better economic performance? Innovations are not an end in themselves but are aimed at improving the firm's competitiveness and performance. Hence, in the end they have to be assessed on the basis of their economic success or, more generally, on the basis of their impact on relevant firm performance measures (Janz, 2003).[4]

This monograph aims at mainly contributing to the third question in this respect as it empirically studies and reports new results on the following three key topics:

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[1] The most important initiatives are the *Partner for Innovation Initiative*, in cooperation with industry and science, and the *Innovation and Future Technologies in Small and Medium-Sized Companies – High-Tech Master Plan*. The purpose of the latter programme is, among others, to improve the access to venture capital for small and medium-sized firms.

[2] The role of venture capital in fostering innovation was analysed, for instance, by Kortum and Lerner (2000) for US or Engel and Keilbach (2007) for German firms. The impact of financial constraints were investigated, for instance, by Kukuk and Stadler (2001). Rammer, Peters et al. (2005) examined the importance of different barriers to innovation in Germany.

[3] In 2003, the R&D intensity, i.e., the ratio of R&D expenditure to GDP, amounted to 2.55 in Germany, compared to 1.89 in the UK, 2.19 in France, 3.98 in Sweden, 1.95 in the EU15, 1.94 in Canada, 2.60 in the US, 3.15 in Japan and an OECD average of 2.24 (OECD, 2005c).

[4] Hauschildt (2004) distinguishes three kinds of success which can be associated with the introduction of new products or processes: Technical success, economic success and other effects, like environmental or social effects. The present study focusses solely on the economic success of innovations. Grupp (1997) subdivides economic success indicators of innovations into direct and indirect measures. Direct success or output indicators are the number of innovations, the share of sales due to new products or innovation rents. On the other hand, indirect success indicators measure the impact of innovation on central performance indicators, like productivity, employment, exports or profits, on the basis of an economic model. This kind of analysis is much more common in empirical innovation research.

1. How does innovation affect the employment growth of firms?
2. Does innovation increase firms' productivity performance?
3. Do firms innovate persistently over time?

The outline of this monograph and the research strategy for each topic together with some more background information and the contribution of each topic to the existing literature will be explored in the following section.

1.2 Background, Outline, and Research Strategies

Analysing and quantifying the effects of innovation activities on productivity and employment has a long tradition in empirical research relating to industrial organisation. In the 1990s, research on productivity results in particular was reinforced by new theoretical underpinnings from the endogenous growth theory, emphasising that economic growth is positively correlated with investments in research (Romer, 1986; 1990) and human capital (Lucas, 1988). Surveys by Mairesse and Sassenou (1991), Griliches (1995), and Bartelsman and Doms (2000) provide a useful overview of empirical evidence on productivity effects. An overview of empirical studies linking innovation and employment can be found, for instance, in Spiezia and Vivarelli (2002) or Chennells and van Reenen (2002). But despite a large number of empirical studies, Griliches (1994) argued that innovation research has only been partly "successful" in measuring the effect of innovation on productivity. That is, many studies only found a modest (and sometimes insignificant) coefficient of R&D which is not large enough to account for much of the productivity development in the 1970s and 1980s.[5] These results have caused some concern as to whether the methods and data applied have been accurate since theoretical models would suggest a significantly large contribution of innovation to productivity. In addition to the problem of measuring output in some industries as well as selectivity and endogeneity problems in econometric regressions, one reason for that may be the difficulties of adequately measuring innovation.

For a long time empirical innovation research has focussed on input-oriented innovation indicators when measuring aspects of innovation. In particular, R&D-based indicators, like R&D expenditure or R&D employees or corresponding intensities, served as proxies for innovation. The use of R&D-based indicators has considerably benefited from the development of a unique definition of R&D which was promoted by the US National Science Foundation (NSF) and the OECD and which was codified in the Frascati Manual (see OECD, 2002; first published in 1964). R&D has the advantage of providing well-codified and internationally comparable data. But the literature

[5] In many industrialised countries, it has even been observed since the 1970s that, at the aggregate level, R&D expenditure has risen continuously while at the same time productivity growth slowed down. This is known as *productivity paradox* in the literature.

states at least three objections to using R&D. First of all, R&D is not the only way for an enterprise to introduce new products and processes. That is, R&D, although important, is only one aspect of the innovation process, and using R&D indicators tends to lead to the underestimation of innovation activities in small and medium-sized firms as well as service sector firms (see, e.g., Kleinknecht, 1987; Brouwer and Kleinknecht, 1997). Secondly, it is presumably not the input of innovation activities but rather their outcome that exercises influence over the firm performance (Blundell, Griffith, and van Reenen, 1995). Thirdly, R&D or more general innovation expenditure transforms into product as well as process innovations, and, from a theoretical point of view, both affect employment or productivity via different channels.

Patents, most of all patent application counts but, in recent years, also value-based patent indicators, have been used as an option to overcome these deficiencies. But patent-based indicators have been heavily criticised as being a poor yardstick for innovative outcome (see, e.g., Scherer, 1965; Griliches, 1990). Not all inventions are patented and not all patented inventions lead to marketable innovations. Additionally, patents not only represent the outcome of the innovation process but also serve as an instrument to protect the returns of innovation and, hence, are subject to strategic considerations of firms. For many industries, in particular for large parts of the service sector industries, patents only play a minor role in appropriating returns on innovation. Furthermore, a fundamental shift in the role of patents has been ascertained since the beginning of the 1990s. This is expressed in a steep increase in the number of patents which is not associated with an increase in R&D expenditure but accompanied by a decrease in the importance of patents as a method of protection. Hall and Ziedonis (2001) called this the *patent paradox*, and several aspects are blamed for this shift: Firstly, the increasing importance of cumulative technologies implies that a single innovation is increasingly protected by several patents. Secondly, firms use patents more often as a strategic instrument to block competitors. Thirdly, firms use patents as a subject for strategic negotiations, for instance, for merger negotiations, cross-licensing of patents (Eswaran, 1994), or licensing of patents pools (see Shapiro, 2001; Lerner, Tirole, and Strojwas, 2007).

Since the mid 1990s, another strand has become more significant in empirical innovation research, focussing on survey-based innovation indicators. This literature has greatly benefited from the adoption of the Oslo Manual (OECD and Eurostat, 1997; first published in 1992) as well as the release of new and internationally harmonised surveys, which were initiated in the first half of the 1990s and which are known as the Community Innovation Surveys (CIS) in Europe. The Oslo Manual provides a unique definition of innovation and recommendations on some useful direct innovation output indicators. These measures allow me to distinguish the impact of product and process innovations, and – compared to patents – they are less affected by firms' strategic considerations. The studies in the present monograph follow this general line of empirical innovation research.

Since all studies are mainly based on data from the German CIS, which is conducted as an annual panel survey called the Mannheim Innovation Panel (MIP), *chapter 2* starts with a general description of the data set. This includes information on the survey methodology, the innovation concept, and the definition of innovation indicators as well as the variables surveyed. The chapter concludes with some stylised facts on the innovation activities of German firms at the aggregate level over the last 10 years using various innovation input and output indicators.

Chapter 3 examines the impact of innovation on the employment performance of firms. From a theoretical point of view, there are different channels through which product and process innovations can destroy or create employment. After a brief theoretical and empirical literature review, a theoretical multi-product model is developed.[6] The model establishes a theoretical link between the employment growth and both product and process innovation output, and it allows me to disentangle some of the theoretical employment effects under certain assumptions. Furthermore, it is tailor-made for analysing the effects of innovations on employment at the firm level using specific information provided by CIS data. Based on this new model, the empirical analysis pursues three different aims. First of all, I seek to estimate the effects of product and process innovations on employment in German manufacturing and service firms. Despite its rising importance in terms of the number of employees, there is hardly any empirical evidence on displacement and compensation effects of innovation activities in the service sector, and the analysis is intended to fill this gap. In a second step, I extend the model to examine the impact of different kinds of product (new to the market and new to the firm) as well as process innovations (cost reducing or quality enhancing) and to test whether employment effects differ according to the type of innovation. Finally, the question is investigated whether a common pattern in the link between innovation and employment exists among four large European countries (Germany, France, Spain, and the UK), which demonstrated a very different economic development over the last 10 years in terms of employment and productivity growth (see Fig. 1.1).

Chapter 4 studies the impact of innovation on firm-level productivity. Empirical studies traditionally used a production function approach as their theoretical framework, augmented by knowledge capital as an additional input. The knowledge capital was usually measured by an R&D capital stock in the level formulation (see, e.g., Griliches, 1986; Griliches and Mairesse, 1983) or R&D investments (per output) in a growth rate specification (see, e.g., Griliches, 1986; Link, 1981). This traditional approach suffers from at least two main deficiencies. Firstly, the innovation process, that is the link between

[6] The theoretical model was developed in a joint paper together with Rupert Harrison (Institute for Fiscal Studies and University College, London), Jordi Jaumandreu (Universidad Carlos III de Madrid), and Jacques Mairesse (Crest-INSEE, Paris) (see Harrison, Jaumandreu, Mairesse, and Peters, 2005).

the resources dedicated to innovation and the innovative outcome, remains a black box. Secondly, only some of the firms are engaged in R&D or in innovation activities in general, and it is well-known that a restriction to the selected (innovative) sample may induce biased estimates (Heckman, 1979). A huge step forward was taken by Crépon, Duguet, and Mairesse (1998) who addressed both of these problems. They developed an empirical model, which is known as CDM model in the literature and which was the first to connect innovation input, innovation output, and productivity. Crépon et al. estimated their model for French manufacturing firms, and a growing number of studies for other countries followed this line of research (see, e.g., Lööf and Heshmati, 2002, for Swedish firms; Klomp and van Leeuwen, 2001, for Dutch firms; Janz, Lööf, and Peters, 2004 for a cross-country comparison between Germany and Sweden). The study presented in chapter 4 will also rely on this model. One drawback of the studies so far is that they only take into account a measure for product innovation output although innovation input is related to both product and process innovation. The empirical analysis aims to extend the model by distinguishing between the output of product and process innovations and to analyse whether different factors are crucial to their success.

The research of *chapter 5* is motivated by the recent empirical evidence that firm performance in terms of productivity is highly skewed and that this heterogeneity is persistent over time (for an overview, see Dosi, Marsili, Orsenigo, and Salvatore, 1995; Bottazzi, Dosi, Lippi, Pammolli, and Riccaboni, 2001; Bartelsman and Doms, 2000).[7] Since innovation is seen as a major determinant of a firm's growth, one hypothesis is that the permanent asymmetry in productivity is due to permanent differences in innovation behaviour. So far, however, little is known about the dynamics in firms' innovation behaviour, and the evidence is mostly based on patents (see Geroski, van Reenen, and Walters, 1997; Malerba and Orsenigo, 1999; Cefis, 2003a). Therefore, chapter 5 particularly focusses on the following two research questions: (i) Do firms innovate persistently over time or is there a steady entry into and exit from innovation activities? Persistence occurs when a firm which has innovated in one period innovates once again in the subsequent period. (ii) If persistence is prevalent, what drives this phenomenon? It might be traced back to a causal effect of past innovation on future innovation (true state dependence). Economic theory suggests several arguments both in favour of and against state dependence at the firm level which will be explored in detail in section 5.2. Alternatively, firms may possess certain characteristics which make them more likely to innovate. To the extent that these characteristics themselves show persistence over time, they will induce persistence in innovation behaviour. To test the hypothesis of true state dependence, the study presented in chapter 5 applies a dynamic random effects binary choice model

[7] A related strand of literature investigates the persistence of excess profits. The majority of these studies have found some evidence for profit persistence, e.g., Mueller (1977), Geroski and Jacquemin (1988), or Cefis (2003b).

employing a new estimator recently proposed by Wooldridge (2005) for this kind of model. This panel data approach allows me to control for individual heterogeneity – a potential source of bias which was not taken into account in most of the previous empirical studies due to data restrictions.

Chapter 6 summarises the main findings of interest and draws some conclusions.

2

Data Set and Descriptive Analysis

The subsequent empirical analyses on employment, productivity, and persistence effects of innovation activities are mainly based on the Mannheim Innovation Panel (MIP). This chapter first presents some general background information on the data set including the survey methodology, response rates, and the information collected. It then provides the basic definitions of several innovation indicators which will be applied in the subsequent empirical analyses. The knowledge about the firms can be enriched by merging the MIP with other data sets. Therefore, a short description of the information used from other data sources follows. The chapter concludes by portraying the innovation activities of German firms at the aggregate level over the last 10 years using various input- and output-oriented innovation indicators.

2.1 Mannheim Innovation Panel

2.1.1 Survey Methodology

In Germany, the Centre for European Economic Research (ZEW) in cooperation with infas Institute for Applied Social Sciences runs two different but complementary innovation surveys on behalf of the German *Federal Ministry of Education and Research (BMBF)*.[8] The first covers industrial firms, i.e. firms from the manufacturing, mining, energy, water, and construction sectors. The second survey is the counterpart for services, comprising a great part of the service sector: retail, wholesale, transport, real estate and renting, financial intermediation, computer services and telecommunications, technical services (architectural and engineering activities, technical testing and analysis, R&D), consultancies (legal, accounting and auditing activities, advertising), other business-related services (e.g., cleaning, security, provision of

[8] Between 1995-1998, the survey in the service sector was cooperative work of ZEW, infas, and Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe.

personnel, waste management), and media. Table 2.1 provides the definition of the branches of industry. The surveys are called "Zukunftsperspektiven der deutschen Wirtschaft" and "Dienstleistungen der Zukunft" in the industry and service sector, respectively, and together they make up the Mannheim Innovation Panel (MIP). At the beginning, the questionnaires differed slightly between the two surveys, but since 2001 they have been identical.

Table 2.1: Branches of Industry Covered by the MIP

Industry Sector		Service Sector	
Branches of Industry	NACE[a)]	Branches of Industry	NACE[a)]
Mining	10-14	Distributive services	
Manufacturing		Wholesale	51
Food	15-16	Retail/repairing	50, 52
Textile	17-19	Transport/storage/post	60-63, 64.1
Wood/paper/printing	20-22	Real estate/renting	70-71
Chemicals	23-24	Business-related services	
Plastic/rubber	25	Banks/insurances	65-67
Glass/ceramics	26	Computer/telecom-	72, 64.2
Metals	27-28	munication	
Machinery	29	Technical services	73, 74.2-74.3
Electrical engineering	30-32	Consultancies	74.1, 74.4
MPO[c)] instruments	33	Other BRS[b)]	74.5-74.8, 90
Vehicles	34-35	Media[d)]	92.1-92.2
Furniture/recycling	36-37		
Energy	40		
Water	41		
Construction	45		

Notes: [a)] The industry definition is based on the classification system NACE Rev.1 (Nomenclature générale des activités économiques dans les Communautés Européennes) as published by Eurostat (1992) using 2-digit or 3-digit levels.
[b)] Business-related services.
[c)] Medical, precision, and optical instruments.
[d)] The media industry has been part of the target population since 2003.

For the industry sector, the survey started in 1993, and 2 years later the service sector followed.[9] Both surveys are conducted annually, although there was a break in the service sector in 1996. This study makes use of data from

[9] The first two waves in the industry sector already included some selected service industries. Detailed information on the first wave can be found in Harhoff and Licht (1994). A description of the MIP can also be found in Janz, Ebling,

the surveys 1993 to 2004 which means that there are 12 and 9 waves at hand for the industry and for the service sector, respectively.[10] As mentioned before, the survey methodology and definitions of innovation indicators are strongly related to the recommendations on innovation surveys set out in the Oslo Manual (see OECD and Eurostat, 1997; first published in 1992), thereby yielding internationally comparable data on the innovation activities of German firms. In 1993 (CIS 1), 1997 (CIS 2), and 2001 (CIS 3), the surveys represented the German contributions to the Europe-wide harmonised Community Innovation Surveys (CIS), which take place every 4 years under the coordination of Eurostat to investigate firms' innovation activities.

The target population spans all legally independent enterprises[11] with 5 or more employees and their headquarters located in Germany. An enterprise is defined as the smallest combination of legal units operating as an organisational unit producing goods or services. However, very few large firms have their business units merely subordinated rather than organised as legally independent subsidiaries. These large firms constitute an exception as they are split up according to their business units.

In contrast to other European countries, there is no business register available in Germany. The data on firm, employment, and revenue figures for the target population in the industry sector are based on publications of the German Federal Statistical Office.[12] Due to large gaps in the official statistics, the target population for the service sector is constructed using information from the Federal Statistical Office,[13] the German Central Bank, and various federal commissions and associations.[14] The size classification structure in the service sector is mainly based on estimates by the ZEW.

Due to the lack of a business register, the samples cannot be drawn from the target population itself, so the Creditreform database is used as a sampling frame instead. Creditreform (abbreviation of *Verband der Vereine Creditreform e.V.*) is the largest and most important credit-rating agency in Germany

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Gottschalk, and Niggemann (2001) or Janz, Ebling, Gottschalk, and Peters (2002).

[10] In 2007, the time of publication, two additional waves are available.

[11] Note that in the remainder of this book the terms *enterprise* and *firm* will be used interchangeably.

[12] Publications used are Reihe 4.1.2, 4.2.1, 6.1 and 5.2 of the Fachserie 4; see Statistisches Bundesamt (b; c; d; e).

[13] The information stems from different years of Reihe 4 of the Fachserie 6 (for wholesale and retail trade) and of Reihe 2, 3, 4 and 8 of the Fachserie 8 (for transport); see Statistisches Bundesamt (f; g; h; i; j). Additional information is gained by the turnover tax statistics.

[14] E.g., *Bundesamt für Güterverkehr*, *Bundesaufsichtsamt für Finanzdienstleistungen*, *Bundesverband deutscher Banken*, *Verband privater Bausparkassen*, *Bundesgeschäftsstelle der Landesbausparkassen*, *Gesamtverband der Deutschen Versicherungswirtschaft*.

and has the most comprehensive database of German firms at its disposal, which it provides to the ZEW for research purposes. Amongst other information, the database includes the name and address of the firm, contact person, industry classification, region, and the number of employees. Both samples are drawn as stratified random samples and are representative of the corresponding target population. Firm size, industry, and region serve as stratifying variables. Based on the number of employees, 8 size classes are distinguished: 5-9, 10-19, 20-49, 50-99, 100-199, 200-499, 500-999, and 1,000 and more employees. Due to the small number of large service firms, the last two categories are merged in the service sector. With regard to the region, the sample is stratified into West and East Germany. East German firms are defined as those firms that have their head office in one of the following six federal states: Berlin, Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt, and Thuringia. Subsidiaries of West German firms in East Germany that are not organised as separate legal entities are not part of the East German enterprise sector as used here. The industry classification scheme used for stratification purposes is generally based on the 2-digit NACE level; however, in the service sector the 3-digit level is applied for some industries (see Table 2.1).

The sampling is disproportional, that is the drawing probabilities vary between cells. Large firms, firms belonging to more heterogeneous cells (according to labour productivity) or to industries with a small number of firms, and East German enterprises have a higher probability of being sampled. The disproportionate sampling of the first three groups is indispensable to produce reliable projections, in particular of quantitative variables. Large firms may, for example, generally be characterised by idiosyncratic innovation behaviour but determine all quantitative variables to a very large extent. The fact that East German enterprises are oversampled is mainly explained by their very different level and dynamic of development compared to West German firms at the beginning of the 1990s. The disproportionate sampling implies that the distribution of firms across cells in the gross sample differs from that in the target population. As an example, the Tables 2.2, 2.3, and 2.4 show the distribution of firms by region, size, and branches of industry in the target population and in the gross sample of the 2001 surveys (CIS 3), which are used for the empirical analyses in the chapters 3 and 4. The pattern is similar for other years.

Tables 2.2-2.4 further show the gross sample rate, which is defined as the ratio of the gross sample to the target population. For the industry sector, this rate amounts to 4.7%. However, the proportions vary considerably between branches, and the low overall rate is mainly due to the dominant role of the construction industry with its minimal value. Excluding construction, the proportion of the target population included in the gross sample comes to 14.5% (see Table 2.3). Similarly, retail is responsible for the low overall proportion of 3.0% in the service sector. Since 2005, both industries have been excluded from the target population.