MARKET INSTITUTIONS AND FIRM BEHAVIOUR: EMPLOYMENT AND INNOVATION IN THE FACE OF REFORM

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I, Gareth James Macartney, declare that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated.

Signed:

Date:

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ABSTRACT

This thesis investigates the effect that market institutions have on economic outcomes such as employment and innovation. The market institutions under study are those that determine the conditions in product, labour and capital markets. Of particular interest is how the effect of institutional changes in one market depends on the conditions in another, or depends on the nature of innovation by the firm. The first chapter describes the matching of patents at the European Patent Office to firm accounts data for all registered firms across fifteen European countries. This constitutes a valuable new dataset for research in innovation that is used for much of the empirical work in this thesis. The second chapter investigates the impact of product market competition on unemployment, and how this depends on labour market institutions. It uses differential changes in regulations across OECD countries to find that increased competition reduces unemployment, more so in countries with strong unions. The third chapter investigates how the effect of product market competition on innovation depends on financial institutions. Using exogenous variation in competition in manufacturing industries this chapter finds that the positive effect of competition on innovation is larger in countries with good financial institutions. The fourth chapter investigates the effect of employment protection legislation on innovation. The theoretical effect of employment protection legislation on innovation is ambiguous, and empirical evidence is thus far inconclusive. This chapter finds that within multinational enterprises overall innovation occurs more in subsidiaries located in countries with high employment protection, however radical innovation occurs more in subsidiaries located in countries with low employment protection.

Contents

INTRODUCTION

Modern industrial societies have entrusted the job of delivering economic growth to corporations. Governments determine institutions in product, labour and capital markets, leaving firms to choose optimal output and innovation based on competitive conditions and factor prices. Much of the recent effort by regulators to increase growth, has focused on the effect on firms' incentives from institutional reform in these markets *in isolation*. The purpose of this thesis is to empirically investigate how the impact of reforms in one market (the product market, say) depends on the conditions in another market (the labor market, say).

Recent academic work has found that institutions do affect economic outcomes. In general, less heavily regulated financial markets are associated with higher growth (see Levine 2005 for a survey), less regulated labor markets are associated with lower unemployment (Nickell et al. 2005, Blanchard and Wolfers 2000) and, on average, more competitive product markets are associated with more innovation (Nickell 1996, Blundell et al. 1999). These results are reflected in the popular view of mainstream economics and form much of the current policies for reform (for example, the European Union's Lisbon Agenda). There is, however, theoretical and empirical evidence of more complex relationships. For example, increased product market competition has negative effects on innovation in initially technologically backward sectors (Aghion et al. 2005). Strict labor regulations may lead to unemployment through higher wage costs, but they may also increase workers' commitment to invest in productivity enhancing innovation (Acemoglu 1997).

This thesis finds three main results that further our understanding of how changes in institutions have differential effects on economic outcomes. Each of these results are explained by conventional models of industrial organization and growth. The results are:

- Increased product market competition decreases unemployment, but more so where labour market institutions give workers high bargaining power;
- Increased product market competition increases innovation more so in economies where good financial institutions have facilitated a high initial level of technology; and,

- Employment protection legislation encourages simple low-tech innovation, but discourages high-tech innovation.

In addition to the relevance for employment and growth enhancing policies, the work increases our understanding of and the support for models of firm incentives. Each chapter, although primarily empirical in nature, develops or describes a theoretical model to explain and motivate the results. The empirical investigations use cross-industry, cross-country and cross-time variation in institutional variables in conjunction with firm level innovation data. Fixed effects are used to control for permanent unobservable differences in countries, industries or firms, depending on the data available. The author constructed the dataset that underpins most of this empirical study. This highly valuable data source was constructed by matching firm level accounts data for all registered firms in fifteen countries to their patent applications.[1] The creation and description of this dataset is the topic of the first chapter.

The thesis proceeds as follows:

Chapter 1 | Matching Patents to Firms' Accounts

This paper describes a new dataset that matches patent applicants at the European Patent Office to firm accounts data in Amadeus for all registered firms across fifteen European countries. The result is a valuable source of information on innovation at the firm level, linking data on firm accounts, industry sector and ownership with patent counts, citations and inventor data. The first part of the paper describes the matching process on detail and quantifies its success. The second part of the paper describes the new dataset and: i) investigates how measures of innovation intensity based on patents relates to measures based on R&D expenditures from an external source; ii) investigates the relationship between patenting and firm size; and, iii) introduces a measure of scientific complexity based on citations and relates this to how patenting is concentrated across firms.

[1] The dataset increase the selection of firm level patent datasets available to the researchers. It adds to the existing Leverhulme dataset for listed UK firms and the NBER dataset for listed US firms (Hall et al. 2001). The new dataset's usefulness comes from the fact that the sample covers fifteen European countries and the fact that it contains both large listed firms and small unlisted firms.

Chapter 2 | Product Market Reforms, Labour Market Institutions and Unemployment (joint with Rachel Griffith and Rupert Harrison)

We analyze the impact of product market competition on unemployment, and how this depends on labour market institutions. Theoretically, both firms with market power and unions with bargaining power are constrained in their behaviour by the elasticity of demand in the product market. We use differential changes in regulations across OECD countries over the 1980s and 1990s to identify the effects of competition. We find that increased competition reduces unemployment, more so in countries with labour market institutions that increase worker bargaining power. We also find that competition increases real wages, but less so when bargaining power is high.

Chapter 3 | Product Market Competition, Financial Institutions and Innovation

This paper finds evidence of complementarities between product market competition and financial institutions, as determinants of innovation. Recent research has found that product market competition increases innovation, particularly in sectors that are technologically advanced, i.e. have high initial innovation rates. Financial institutions that reduce monitoring costs faced by investors are theoretically associated with higher innovation rates. We find that increased competition has a bigger effect on innovation in the presence of such financial institutions. We use exogenous variation in competitive conditions across manufacturing industries and European countries that arose due to the adoption of the Single Market Programme. The positive effect of competition on innovation is found to be bigger in countries with more numerous credit institutions and lower deposit insurance. The results are robust to controlling for other institutions that may affect the competition-innovation relationship.

Chapter 4 | Employment Protection Legislation, Multinational Enterprises and Innovation (joint with Rachel Griffith)

The theoretical effects of labour regulations such as employment protection legislation (EPL) on innovation is ambiguous, and empirical evidence is thus far inconclusive. EPL increases job security and the greater enforceability of job contracts may increase worker investment in innovative activity. On the other hand EPL increases adjustment costs faced by firms, and this may lead to under-investment in activities that are uncertain including innovation and other technologically advanced activities. In this paper we find empirical evidence that multinational enterprises locate more innovative activity in countries with high EPL, however they locate technologically advanced innovation in subsidiaries located in countries with low EPL.

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CHAPTER 1 | MATCHING PATENTS TO FIRMS' ACCOUNTS

Gareth Macartney

Abstract

This paper describes a new dataset that matches patent applicants at the European Patent Office to firm accounts data in Amadeus for all registered firms across fifteen European countries. The result is a valuable source of information on innovation at the firm level, linking data on firm accounts, industry sector and ownership with patent counts, citations and inventor data. The first part of the paper describes the matching process on detail and quantifies its success. The second part of the paper describes the new dataset and: i) investigates how measures of innovation intensity based on patents relates to measures based on R&D expenditures from an external source; ii) investigates the relationship between patenting and firm size; and, iii) introduces a measure of scientific complexity based on citations and relates this to how patenting is concentrated across firms.

Acknowledgements: The analysis contained in this paper was funded by the ESRC/EPSRC Advanced Institute of Management Research (AIM) and the ESRC Centre at the IFS. The creation of the dataset was part of a joint IFS-CEP (Centre for Economic Performance) project involving Laura Abramovsky, Sharon Belenzon, Nick Bloom, Rachel Griffith, Rupert Harrison and John Van Reenen, the author's specific contribution was the matching and validation of the dataset described herein. The author would also like to thank Bronwyn Hall, Suzanne Prantl, Grid Thoma, Colin Webb and participants at the European Policy for Intellectual Property 2006 workshop in Milan for helpful comments and suggestions. Responsibility for any results, opinions, and errors lies with the author alone.

1. INTRODUCTION

Many questions in economics focus on innovation by corporations. How do industry characteristics affect firms' incentives to innovate? How do firms finance innovation? How do national institutions affect firms' incentives to innovate? How much innovation is carried out by incumbents rather than entrants? How does firm ownership relate to innovation? Such questions call for firm level measures of innovation that can be linked to industrial sectors and accounting data, for a population of large and small firms, across different countries. This paper describes the creation of such a dataset, achieved through the matching of firm names in the accounting system Amadeus to applicant names from the European Patent Office (EPO). The dataset provides a measure of firm level innovation that is consistent across countries, as an EPO patent is a well defined object that follows strict administrative rules. As important is the sheer richness of patent data. Figure 1.1 shows a typical EPO patent document, containing information on the applicants, the inventors, the technology classification, the date of application, and the date of granting. Additionally, patents must cite other patents that they are technologically related to, giving a measure of the importance of the invention by way of patent citations. Patents also cite academic journals, enabling researchers to link patented technology to fundamental scientific research. Linking this information, as we have done, to time varying accounts data including firm ownership, asset size, employees, industry sector, indebtedness and cash flow for a very large population of firms gives a dataset able to facilitate very many research applications.[2]

[2] Amadeus is produced by Bureau van Dijk Electronic publishing (see http://www.bvdep.com/en/companyInformationHome.html).

Figure 1.1: A Typical EPO Patent

Publication Number:	WO/2005/104585	**International Application No.:**	PCT/EP2005/003903
Publication Date:	03.11.2005	**International Filing Date:**	14.04.2005

Int. Class.: *H04Q 7/32* (2006.01), *H04Q 7/22* (2006.01)

Applicants: **VODAFONE HOLDING GMBH** [DE/DE]; Mannesmannufer 2, 40213 Düsseldorf (DE) *(All Except US)*.
WEBER, Elmar [DE/JP]; B2807, 6-12-2 Roppongi, Minato-ku, Tokyo 106-0032 (JP) *(US Only)*.
STEPHENS, David [GB/GB]; Jasmine Cottage, Craven Road, Inkpen, Hungerford, Berkshire RG17 9DZ (GB) *(US Only)*.
AGUILERA, Maria [ES/ES]; C/Infanta Micaela, 15. 5A, C.P. 28050 Madrid (ES) *(US Only)*.

Inventors: **WEBER, Elmar** [DE/JP]; B2807, 6-12-2 Roppongi, Minato-ku, Tokyo 106-0032 (JP).
STEPHENS, David [GB/GB]; Jasmine Cottage, Craven Road, Inkpen, Hungerford, Berkshire RG17 9DZ (GB).
AGUILERA, Maria [ES/ES]; C/Infanta Micaela, 15. 5A, C.P. 28050 Madrid (ES).

Agent: **WEISBRODT, Bernd**; Münzstrasse 34, 47051 Duisburg (DE).

Priority Data: 10 2004 020 395.4 23.04.2004 DE

Title: (EN) LOADING APPLICATION PROGRAMS SPECIFICALLY SELECTED BY A USER IN MOBILE TERMINALS
(DE) LADEN VON NUTZERINDIVIDUELL AUSGEWÄHLTEN ANWENDUNGSPROGRAMMEN IN MOBILE ENDGERÄTE

How good are patents as a measure of innovation? Griliches (1990) notes, patent statistics "…are available; …are by definition related to inventiveness, and … are based on what appears to be an objective and only slowly changing standard". Our dataset has some advantages over a widely used measure of innovation in the form of declared R&D expenditure. Firstly, R&D expenditure is available at the aggregate industry level in the ANBERD dataset[3], but is often not available at the firm level, and certainly not for small and medium sized firms. Secondly, the tax treatment of R&D expenditure differs significantly across countries, whereas patent applications and grants at the EPO must adhere to an objective standard irrespective of the country of origin of the applicant.[4] Thirdly, unlike patents, R&D expenditure data brings no supplementary information: we observe simply that a dollar was spent on research and development, we do not observe if an invention resulted, who invented it, where the research was performed, what type of technology was invented or anything else. Of course patents are by no means a perfect measure of innovation (see Griliches 1990 for a survey on the uses of patent statistics). Many productivity enhancing innovations do not require patenting and certain industrial sectors traditionally rely on secrecy as a way of protecting their intellectual property.

[3] The OECD's Analytical Business Enterprise Research and Development database. See www.oecd.org.

[4] There are differences across countries in the value of holding a patent at the EPO in that, although technically EPO patents carry the same protection, when it comes to actual litigation this must be carried out in the country of infraction, the cost of which is subject to the efficiency of the courts in that country. See Chapter 3 for discussion.

Patenting may be used by firms to deter entry rather than to protect real innovations, and the illegal strategy of repeatedly patenting the same technology has been observed. Furthermore, the economic value of many patents is very low and its distribution very highly skewed (Schankerman and Pakes 1986, Scherer 1998).[5] Both R&D expenditure data and patents data have been widely used in research and I show in this paper that our patent based measure is highly correlated at the country-industry level with R&D measures from OECD's ANBERD.

Three other datasets are closely related to ours. Firstly, the dataset of Hall, Jaffe and Tratjenberg (2001) which consists of listed US firms in the Compustat accounting system matched to patents at the United State Patents and Trademark Office (USPTO). Secondly, the IFS-Leverhulme dataset (see Bloom and Van Reenen 2002), which consists of listed UK firms in the Datastream accounting system matched to patents at the USPTO. Although the accounts information in these datasets is more detailed than that in Amadeus and has longer time series variation, our dataset has two advantages. One, it is available across a sample of countries, and two, the firm universe consists of both listed and non-listed firms. For researchers this enables the investigation of cross-country patterns of innovation and the investigation of how innovation varies across large and small firms. A third dataset that is very closely related to our dataset is that of Thoma and Torrisi (2007) which contains matches of Amadeus accounts for 2,197 listed European firms and their subsidiaries to patent applications at the EPO. Thoma and Torrisi (2007) differs from our dataset in that it focuses on matching a much smaller sample of firms using a sophisticated similarity string index. The current matching exercise builds heavily on the lessons learnt by the researchers on all three of these projects.

The key challenge in the creation of the dataset is the matching of patent applicants in the EPO to firm names in the accounting system Amadeus. This is no small task given that: i) the matching can only be performed by comparing names, which have been keyed in to each system by hand; ii) company names, corporate extensions and characters sets are very different across countries; and iii) there is a large number of entities in both systems (1.7 million UK firms in Amadeus, for example). These challenges are met by writing computer software that includes a name standardization algorithm that cleans names and converts permutations of corporate legal extensions into standard formats. The match was

[5] However, as mentioned, citations data can be used to distinguish high value patents from low value patents.

performed at different levels of accuracy, including a full name match and a stem name match, and the level of accuracy of each match is recorded for the researcher. Where possible the Derwent (2000) industrial standard for converting corporate extensions to standard formats for many different countries was followed. Multiple matches are resolved using supplementary information, such as applicant/firm address, where available. Persistent conflicts and mismatches are resolved manually, and the software incorporates these corrections into the dataset. The design of the software is modular, in that separate components can be executed independently of one another. For example, the name standardization procedure can be called from any dataset simply specifying the variable that contains names to be standardised; the matching procedure will match any two datasets with the relevant variables. Therefore, this project makes two contributions for researchers in this area: firstly, the matched dataset and secondly, the matching software which, once publicly available, can be used to construct similar datasets.

This paper separates into two distinct sections. Section 2 describes the data sources and the matching process in detail, and measures the success of the match. Section 3 describes the dataset, providing summary statistics and: i) compares the dataset at an industry level to the ANBERD dataset based on R&D expenditure, finding a strong positive correlation between the two measures; ii) investigates how patenting relates to firm size, finding a positive relationship that is diminishing, suggesting that small firms value patent protection more than large firms, as is consistent with the existing literature; and, iii) introduces a measure of the scientific complexity of innovation based on citations, and investigates how this relates to the concentration of patenting across firms within industries. Section 2 and 3 are written to be standalone so that readers who are not matching aficionados can go directly to Section 3. A final section concludes.

2. MATCHING

2.1. Data Sources

2.1.1. Patents

Our source of information on patents is the recently created EPO Worldwide Patent Statistical Database (hereafter PATSTAT), described in European Patent Office (2006). This database has been designed to be the European patent research community's strategic source of patent and citation information. The PATSTAT database is based on the EPO's search dataset: the database used when searching for related innovations as part of the patent approval process. To facilitate this search it contains information on patent applications to the USPTO and all major national patent offices. Although not used in our dataset, PATSTAT is a potentially good source of information for these patents as well, although data quality appears to be less good for data from national patent offices.

The PATSTAT dataset is related to other patent data sources. Another source of EPO patent applications is the EPO Espace Bulletin CD-ROM[6]. This contains all bibliographic and legal status data on all European patent applications and granted patents, although no information on citations. Although very useful as a look-up tool this applications is not as conducive to large sample manipulation as PATSTAT, which was designed for this purpose. Another related dataset is the OECD's Triadic database on the sub-sample of patents that are registered in all three main patents offices: the EPO, the Japanese Patent Office (JPO) and the USPTO. For triadic patents it is possible to match in detailed information on the underlying USPTO patents and companies from the Hall, Jaffe and Trajtenberg (2001) dataset and on the underlying EPO patents and companies from our dataset. Prior to the creation of PATSTAT the best available source for citations data was the OECD's citations database.[7]

Our target population for matching consists of patent applications to the EPO filed between December 1978 and February 2004 by corporate applicants from fifteen selected countries. December 1978 is the date that the EPO first took applications for European wide patent protection, and February 2004 is the most recent month for which we have the PATSTAT dataset. The fifteen countries selected were those thought to innovate the most. Column 1 of Table 2.1 shows the total number of patent applications for each selected country and column 2 shows the total number of applications where at least one of the applicants is a corporation.

[6] For a description of the dataset see the brochure at www.european-patent- office.org.
[7] For the OECD Triadic and Citations databases see www.oecd.org.

Table 2.1: Patents filed at the European Patent Office, 1978-2005

Country	Number of patent applications (1)	Number of patent applications with at least one corporate applicant (2)
United Kingdom	87,786	75,757
Germany	330,029	296,323
Netherlands	59,848	55,841
Finland	15,986	14,869
Sweden	33,825	29,389
Belgium	15,687	12,907
Norway	4,849	3,854
Spain	7,780	5,461
Denmark	10,916	9,532
Italy	54,043	46,688
France	125,854	112,666
Czech Republic	512	335
Poland	566	354
Portugal	421	304
Greece	678	214
Total	748,780	664,494

Corporate applicants are identified as those names that either: i) contain a well known corporate identifier or; ii) do not contain a university or government identifier and are not written in the standard format in PATSTAT for an individual (usually an inventor). A random sample of the resulting classification is then checked manually. We can see from Figure 2.1 that there has been a significant increase in patent applications at the EPO since it was created in 1978. Figure 2.1 shows that this increase is wide-spread for applications from different European countries, the trend in part likely due to substitutions from national patent offices to the EPO and, in later stages, likely part of the well documented general increase in patenting. Figure 2.1 also shows this trend by corporate patent applicants. The evident close within country correlation of “all” patent applications and “corporate” patent applications in Figure 2.1 suggests that our somewhat approximate classification of corporate patenting is at least consistent over time. Patent applications are truncated at 2004. This is because we use the April 2006 version of PATSTAT which contains patents where the application has been published (note, this does not mean granted) and there is a time lag of 18 months between patent filing and publication of the application. Therefore 2003 is an upper limit to the useable sample period of the first version of our dataset.

Figure 2.1: Number of Patent Applications by Year of Application

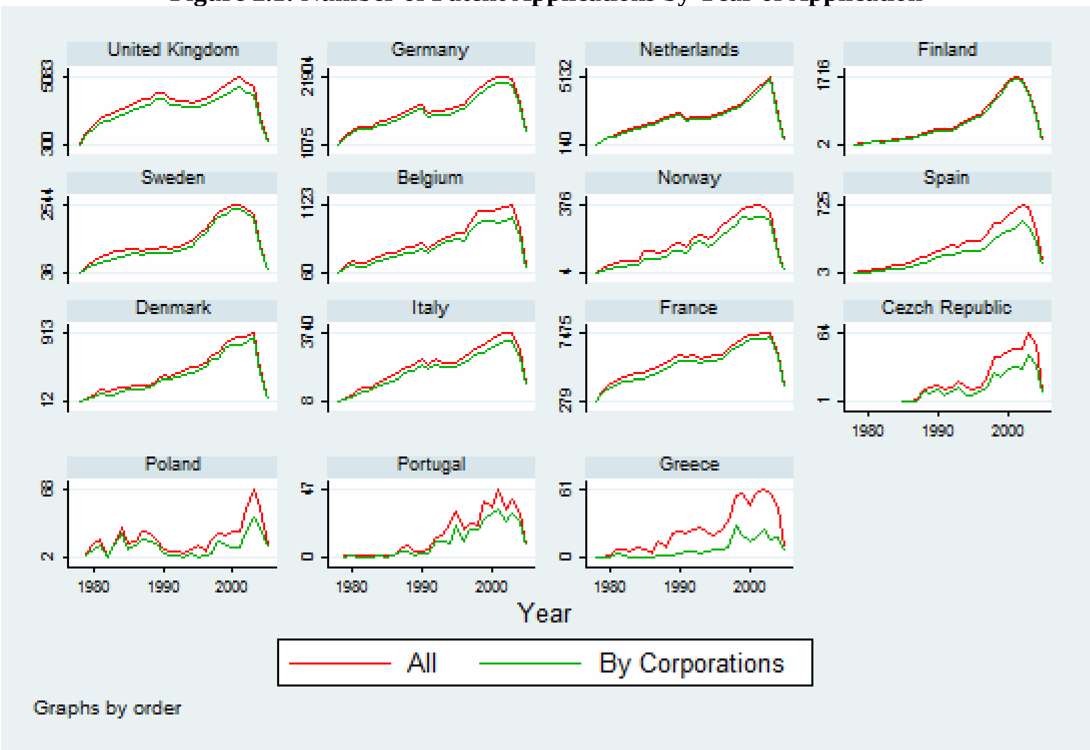
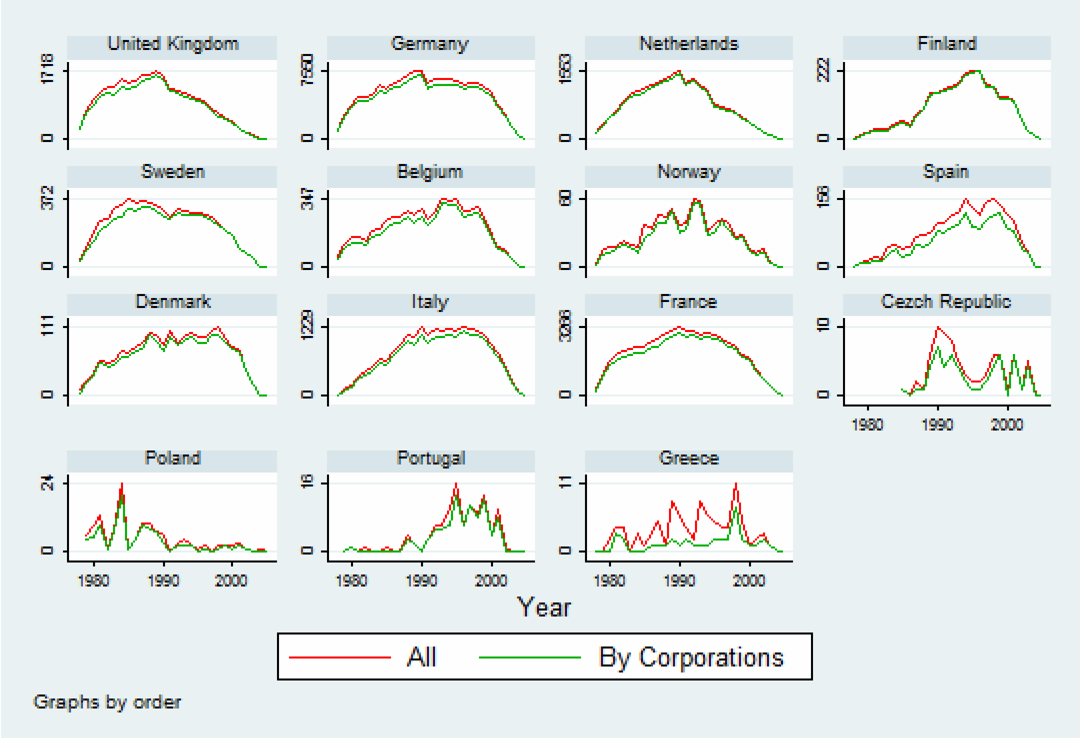


Figure 2.2 shows the number of patent applications by application year, but only for patents that were eventually granted. Again the lines for “all” patent applications and “corporate” patent applications closely follow each other. In all countries the graphs are heavily truncated from around the mid 1990s, due to the lag between patent application and patent granting.

Figure 2.2: Number of Granted Patent Applications by Year of Application



2.1.2. *Accounts*

Our primary source for European company accounts information is Amadeus. Each firm in Amadeus has a unique identifier called a BVD number.[8] Amadeus is available to us for the years 1996, 1997, 1999, 2000, 2001, 2004 and 2006.[9] This dataset contains full accounts going back up to ten years for firms both 'active' and 'inactive' in these years. For each year active firms are those that have filed accounts in that year, whereas inactive firms are those that have not, but *have* filed accounts in at least one of the four preceding years. If a firm does not file accounts for five years that firm is dropped from Amadeus on the fifth year. Accounts are reported unconsolidated for subsidiaries, but are consolidated at the parent level. As well as accounts, information is held on ownership structure and industrial sector. Name changes are not recorded in Amadeus, but are available for UK firms only from the FAME database.[10] Table 2.2 shows the total number of firms for each country in column 1, the number which have an ultimate owner

[8] Although broadly true we shall see that this number is not always a unique identifier of firms, due to poor data quality.
[9] It is very time consuming to download Amadeus data from the CDs, and because each CD holds account data for the preceding ten years and because when firms stop filing accounts (as a result of bankruptcy, say) BVD wait for four years before excluding them, we need not download data for 2002, 2003 and 2005.
[10] Financial Analysis Made Easy. Like Amadeus this is a Bureau van Dijk product, see www.bvdep.com.

recorded by Amadeus in column 2, the number that are recorded as inactive in the most recent Amadeus version in column 3, and the number that appeared in earlier versions of Amadeus but were subsequently dropped due to a lack of account filings for a period longer than four years in column 4.

Table 2.2: Firms in Amadeus

Country	Firms in Amadeus	With Ultimate Owner	Inactive	Dropped
	(1)	(2)	(3)	(4)
United Kingdom	1,989,345	154,077	577,615	21,333
Germany	893,245	39,970	0	109,810
Netherlands	351,906	131,933	22,198	19,658
Finland	90,203	7,095	0	8,940
Sweden	255,428	45,399	11,328	4,110
Belgium	343,439	28,490	11,356	16,263
Norway	174,884	18,755	34,280	1,609
Spain	818,928	37,200	51,580	11,375
Denmark	158,654	27,700	25,298	1,018
Italy	545,281	11,518	21,057	11,561
France	957,429	59,024	29,931	24,289
Czech Republic	49,788	1,246	1,536	1,491
Poland	35,924	2,719	2,025	8,218
Portugal	82,421	4,089	4,758	0
Greece	28,969	1,145	2	2,150

Notes: (1) The number of firms present in at least one of the versions of Amadeus from 1996, 1997, 1999, 2000, 2001, 2004, 2006.
(2) Those in column (1) with an Amadeus ultimate owner.
(3) Those in column (1) that are inactive- have not filed accounts for the last four years.
(4) Those in column (1) that have been dropped from more recent versions of Amadeus.

Although not shown here, the sample of firms increases over time. There are two reasons for this. Firstly, we miss firms that have died prior to 1992 as this is earlier than the earliest edition of Amadeus that we have, 1996, minus the four year retention period for inactive firm accounts. Secondly, the coverage for Amadeus increases over the sample period, with quite an increase in the 2004 edition. These factors mean that our matching success rate increases greatly with time. This may have serious implications for some research applications. Particular attention should be paid to this source of bias in applications where explanatory variables may be correlated with firm deaths, in studies of competition for example. A “safe” sample period in our dataset is 1995 to 2003, where the upper limit is defined by the truncation of patent applications.[11] Naturally, earlier and later years may be useful depending on the research application. It should be noted that we do not try to match on year of activity as well as name, the matching is performed on name alone, so that if a firm is observed in the accounts data from 1999 onwards, say, but observed filing a patent in 1990 then this firm would be successfully matched to that patent, the assumption being that the firm is active even though we do not observe its accounts.

The Amadeus accounts information was downloaded and organised by Nick Bloom and Sharon Belenzon at the Centre for Economic Performance. Sharon Belenzon wrote an algorithm that improved the ownership information in Amadeus. For more information see Belenzon (2007).

2.2. The Matching Process

The goal of matching is to match each corporate patent applicant uniquely to a firm BVD number in Amadeus. The key final output of matching is a list of patent applicant names, the number of patents they have filed, the firm name and BVD number to which they have matched and a code indicating the method by which the match was achieved. Given the very large population of firms in Amadeus we expect to match a very large proportion of corporate patent applicants. Amadeus contains all registered firms in Europe so, if the matching process were perfect, we would expect to match virtually all corporate patent applicants. Of course given the realities of manually entered data into two separate computer systems, PATSTAT and Amadeus, for applicant and company names in fifteen different languages there are significant challenges to be overcome by the process.

The first step of the matching process is to create lists of standardised patent applicant names and standardised firm account names. The next step is to identify the target sample of corporate patent applicants, as non-corporate applicants cannot be matched to firm accounts. The standardised names are then matched together, in the first instance using the full string and in the second instance a “stem” name which has had the corporate legal identifier removed. Where this leads to multiple matches, these are resolved using ownership and address information, or by hand. As there is significant country specific processing the process runs country by country, UK applicants are matched to UK

[11] At the EPO there is delay of 18 months from when a patent application is filed and when the application is published and therefore likely to appear in PATSTAT.

registered firms and so on.[12] At the end of this automated matching process each country is checked manually, with an emphasis on ensuring that very large patenters are matched successfully and known big R&D spenders are accounted for (global companies that spend a lot on R&D are listed in the UK government's R&D scoreboard).[13] The matching process therefore consists of four logical components: name standardisation; automated matching; resolution of multiple matching; and manual matching. A further component records how matching was achieved and measures success. This section describes each of these components in turn, detailing the steps in each process. The software is modular in that each component can be run independently of the others, if given the appropriate inputs. It is generic enough that, with some formatting, it can match any two lists of company names for fifteen different European countries. The actual code is not reproduced here but is available from the author on request, however the name standardisaion rules used in addition to the Derwent (2000) standard and the strings used to identify non-corporate applicants are listed in Table A1 and A2 respectively for reference (see Appendix).

There are many idiosyncrasies in the storage of data in both PATSTAT and Amadeus. The general approach here is one of pragmatism: these quirks are exploited where useful and handled as practically as possible where troublesome.

2.2.1. Name Standardisation

The key problem trying to match EPO applicant names to Amadeus firm names is that the names can be keyed in differently into each system. Therefore we first standardise the names in each system before matching. As a starting point we use the codification suggested in Derwent (2000)[14]. This helps us greatly with standardising commonly used descriptors across the many European countries in our sample, and enables us to harmonise our matching software with other researchers in this field.[15] However, the Derwent list is not exhaustive and we supplement it with name standisation that we have found useful from experience.[16] Essentially, the standardisation involves replacing

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[12] The applicant's country is recorded in PATSTAT and the firm's country of registration is recorded in Amadeus.

[13] www.innovation.gov.uk/rd_scoreboard/downloads/2006_rd_scoreboard_analysis.pdf

[14] See Appendix 2 of Derwent (2000).

[15] The use of Derwent's codification was agreed as a general approach at the EPIP "Patent Data for Economic Analysis" workshop of February 2006.

[16] Our own standardization is listed in Table 2.5.

commonly used strings which symbolise the same thing, for example, in UK company names the strings “Ltd.” and “Limited” are replaced by “LTD”. The process also handles other issues concerned with spaces, punctuation and accented characters. The main steps of name standardisation are as follows:

1. Accented characters are widely used in many European countries. PATSTAT and Amadeus use slightly different character sets and so accented characters are replaced with non-accented equivalents, for example u umlaut becomes “ue”.
2. Convert to upper case characters. Convert “AND”, “ET”, “Y”, “UND” and so on, to “&”. Remove all other punctuation.
3. Create ***standard name*** by replacing corporate extensions with their commonly used acronyms. For example replace “LIMITED” with “LTD”, “SOCIETE ANONYME” with “SA”. Use first the Derwent standard and supplement with further conversions we know to be useful (Table A1). Note that the order in which these commands are performed is key: for example, we must try to convert SOCIETE ANONYME DITE to “SAD” before we can convert SOCIETE ANONYME to “SA”.
4. Create ***stem name*** by taking the ***standard name*** and removing corporate extensions, remembering that in some countries the extension can come at the front of the string.
5. Identify non-corporates. This is unnecessary for Amadeus as all entries are corporate. In PATSTAT identifying non-corporates is essential as many applicants are individuals and some applicants are universities and government departments which will not match to Amadeus. ***Non-corporate individuals*** are identified for PATSTAT as names without recognized corporate identifiers that contain at least one comma in the original applicant name, exploiting the observed pattern that inventor names are always entered in the format “Eddison, Thomas”. ***Non-corporate institutions*** are identified for both PATSTAT and Amadeus as names without recognized corporate identifiers that do contain recognized institutional identifiers, such as “university”. Non-corporates are not removed from the matching process, they are simply flagged so that the success rate of matching can be calculated conditional on corporate entities.
6. Strip out spaces from ***standard name*** and ***stem name***.

As an example, name standardization changes the name “British Nuclear Fuels Public Limited Company” to the ***standard name*** “BRITISHNUCLEARFUELSPLC” and the ***stem name*** “BRITISHNUCLEARFUELS”.

2.2.2. Automated Matching

The matching process is country specific. For a specified country it takes all EPO applicants with applicant country equal to that specified and tries to match them to a list of Amadeus firms registered in that country. The process is iterative in nature, in that it initially tries to match at the highest level of accuracy and, if this fails, it tries to match using more relaxed criteria. The automated matching steps are as follows:

1. Take each patent applicant ***standard name*** and try to match to an Amadeus ***standard name***.
2. For some UK firms the accounting system FAME contains up to four previous company names, which is useful as companies may have changed names since patenting. The matching process takes those UK applicants that have not matched in the first step and tries to match them to standarised old firm names.
3. Take those applicants that have still not matched and try to find an Amadeus firm with the same ***stem name***.

2.2.3. Resolving Multiple Matches

Multiple matches are identified as those where a patent applicant matches to more than one Amadeus BVD number. These occur quite frequently and for several reasons.

Firstly, although rare, different BVD numbers can have the same ***standard name***, particularly if punctuation is used as part of the name. For example the firms “1…Limited” and “1@ Limited” both have the ***standard name*** “1LTD”.

Secondly, the less exact matching using ***stem name*** leads to multiple matches. ***Stem names*** can be common across more than one BVD number, for example across subsidiaries of the same parent firm. For example: “Accent Limited” and “Accent Investments Limited” have the same ***stem name*** “ACCENT”. Multiple matches like this can be resolved using address information, if the patent applicant has the same zip code as one of the Amadeus firm names. Or, failing that, the multiple match can be resolved using ownership information, if both firms are owned by the same parent or if one firm owns the other the patent is ascribed to the owner.

Thirdly, due to poor Amadeus data quality, firms with different BVD numbers can have identical names. For example (name, BVD number):

ADAMS ARMATUREN GMBH DE405067458

ADAMS ARMATUREN GMBH DE4050067458

Often supplementary information is exactly the same suggesting the entries are identical. In this example the date of incorporation is 08/11/1985 for both entries. But the first entry is listed as 'dead' and has a zip code, whereas the second is 'live' and does not have a zip code. Here the BVD is different only in that the second one has an extra zero. Similar examples occur many times for Germany and for some Eastern European countries, always with BVDs that differ only by an extra zero, where most times the record with the extra zero is live and the one without is dead. The exact reason for this is unknown, although it may be due to the merging of different company registration datasets in these countries, where some companies have been registered in more than one system, perhaps once at a local level and once again at a national level.[17] The approximate solution to this is to check if the BVD numbers differ only by an extra zero and if so, assign to the BVD with the extra zero. A similar pattern is observed for Poland although the BVD numbers tend to be different by more than one zero. In the case of Poland, in general where one record is live and the other is not, the live one tends to have the longer BVD, and therefore for Poland the multiple match is resolved by matching to the longer number.

The matching algorithm resolves matches with the following steps, where the order is one of decreasing exactness. The manner of resolution is recorded for the researchers' information.

1. Check if original PATSTAT applicant name (i.e. before standardisation) exactly matches original Amadeus name for one of the Amadeus BVD numbers. If yes, match to this name. This resolves a few rare anomalies such as the example of "1LTD" described above.
2. Check if BVDs have exactly the same firm name and one BVD number is longer than the other. The longer BVD number is more often listed as active than the shorter BVD number, therefore match to the longer BVD number.

[17] This was suggested by Suzanne Prantl as a likely explanation for the case of Germany.

3. Check if zip code held for the PATSTAT applicant appears in the address of the Amadeus firms. If it appears for only one Amadeus firm then match patent applicant to that firm.[18]
4. Check if the ultimate owner BVD numbers are the same for all of the Amadeus firms to which a patent applicant has matched. If yes then assign patent applicant to the ultimate owner BVD number. Similarly, check if one of the Amadeus firms to which the patent applicant has matched owns all of the other firms, if yes then assign the patent applicant to that BVD number.

Unresolved multiple matches are always excluded from the final output.

2.2.4. Manual Matching

The automated matching process can lead to two types of errors:

Type I errors - Missed Matches

These errors occur when the process fails to find a match for a patent applicant, where the correct firm does exist in Amadeus. This will be possible where the main part of the name has been keyed incorrectly into one of the systems ("Marconi" written "Manconi", for example), and will always be a problem with the "exact" matching technique that we have followed. This is probably less of a problem if following the approximate string matching approach adopted by Thoma and Torrisi (2007), although presumably Type II errors will be more likely.

Type II errors – False Matches

These errors occur when the process uniquely matches a patent applicant to the wrong firm. This is most likely to occur with matches on ***stem name***, as this uses a shortened version of the applicant/firm name.

To handle *Type I errors* automatically would require a more advanced matching technique, such as the Thoma and Torrisi (2007) method. For the purpose of our project, which used such a large target population of firms from Amadeus, the cost of writing such advanced software was deemed to outweigh the benefits, especially given the high matching success rates that we have managed to achieve with our technique (as we shall see in the next section). Automatically correcting *Type II errors* is not really feasible

[18] One other attempt was made to resolve matches based on the date of firm incorporation, the idea being that matches to patents filed before the firm incorporated must be invalid. This happened so frequently it was abandoned; it appears that many firms re-incorporate for reasons unknown and that the date of incorporation in Amadeus is useless as an indicator of firm birth.

giving the patchy availability of supplementary data. For example, it is not desirable to only accept a match if the address information also matches as this data is not always available, and where it is, can be different for a variety of trivial reasons, such as small geographical relocations between the time of patent application and the time of most recent accounts filing. Therefore, both *Type I* and *Type II* errors must be checked manually. There is one exception to this in that matches of patent applicants that are identified as ***non-corporate*** to Amadeus firms are always discarded as they are always erroneous. For example the inventor name "Thomson, Martin" will match on ***stem name*** to "Thomson Martin Limited" although they are clearly unrelated. A report containing a list of ***non-corporates*** is produced by the automated matching process and is checked manually, to ensure that ***non-corporates*** have been correctly identified.

Given human resource constraints the emphasis of manual checking has been on ensuring that very large patenters are matched correctly. Manual matching is facilitated by a report produced by the automated process listing patent applicant names, the number of patent applications they have filed, whether or not they have matched, and, if they have matched, the name and BVD number of the firm(s) that they have matched to. To eradicate individual manual matcher bias, a list of steps to be followed was circulated among the team of researchers who performed the manual matching.[19] Broadly, the steps followed were:

1. Attempt to match big patenters that have failed to match (handling *type I errors*). Take part of the applicant name and search in the unprocessed Amadeus files for that string. Search other data sources, such as the internet, for that applicant name. Has it been subject to acquisition? If yes, find new parent firm and assign patents to that firm. Has it been subject to name change? If yes, find new name in Amadeus and assign patent to that firm.
2. Check that firms identified in the R&D Scoreboard as large spenders on R&D are present in the dataset and have matched. If they have not matched then follow procedures in step 1 to find a suitable match. In some instances high R&D spend is not related to patenting; this is normally sector specific, for example there is very little patenting in the software industry as computer software is not normally covered by patent protection.

[19] The manually matching was performed by researchers at the Institute for Fiscal Studies, namely Laura Abramovsky, Rachel Griffith, Rupert Harrison and Gareth Macartney.

3. Check that automated matching has matched big patenters correctly (handling *type II errors*). This is done by sight. Names are visually checked and supplementary information, such as addresses, are ensured to be consistent.
4. Attempt to resolve multiples matches for big patenters that were not resolved by the automated process (*type I errors*). This is done using external data sources, such as the internet, to find information on corporate structure that may enable resolution.
5. Check that multiples matches that have been resolved for big patenters have been resolved correctly (*type II errors*). This is done by sight. Specifically check that if resolved by ownership or address information that this data matches in some reasonable sense across the patent applicant and the matched firm.

2.2.5. Setting Match Codes and Reporting Success

From the full matching process just described, matches between patent applicant and firms can be achieved by a number of methods, each of which indicates a varying degree of exactness. Unresolved multiple matches and matches of identified ***non-corporate*** applicants are excluded from the final output. However, researchers may be more comfortable using only matches on ***standardised name*** and excluding matches on ***stem name***. Or they may wish to use only unique matches and exclude resolved multiple matches. Therefore a code that uniquely defines the type of each match is produced along with final output of applicant names and firm names and BVD numbers. This gives the researcher flexibility in choosing the level of exactness required for their application. The match codes are listed in Table A3 (see Appendix).

The final step of the matching process is to measure success and a report recording success rate for each country is produced automatically. This reports: i) the proportion of corporate patent applicants that have been matched; ii) the proportion of patent weighted patent applicants that have been matched; and iii) the breakdown of these success rates by matching method. These success rates are discussed in detail in the next section.

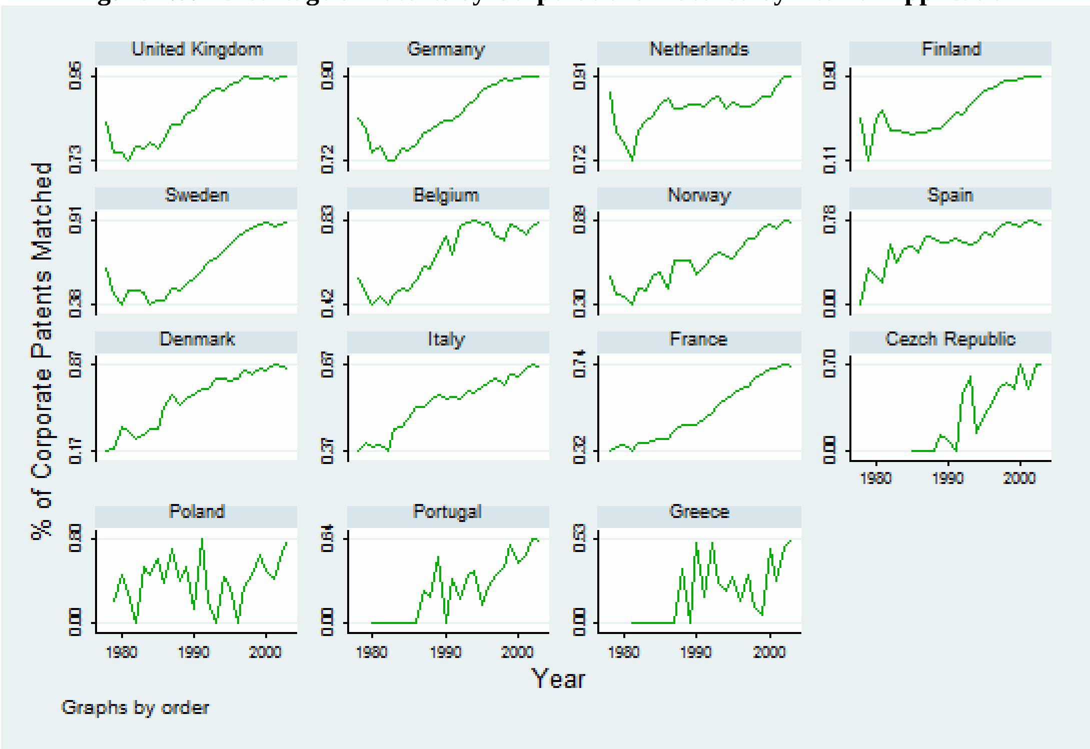
2.3. Matching Results

The first sub-section here describes the success of the matching performed following the process described in Section 2. The second sub-section briefly describes the final output of the process available to researchers.

2.3.1. Measuring Success

Figure 2.3 shows graphs of matching success, measured as the percentage of corporate patents that have at least one applicant matched uniquely to an Amadeus firm, plotted against year of patent application.

Figure 2.3: Percentage of Patents by Corporations Matched by Year of Application



The year of application runs from the opening of the EPO in 1978 to 2003 (the years 2004 and 2005 have been excluded from this graph as patent applications are heavily truncated after 2003, as discussed). The graphs are ordered by average success, with the most successfully matched country coming first and the least successfully matched country coming last. The most successfully matched country is the one that the researchers know most about: the United Kingdom. The ordering of success reflects another bias, namely that countries with a large volume of patenting were given priority over those with low patenting activity. The four least successfully matched countries are also the four lowest patenting countries (Czech Republic, Poland, Portugal and Greece, see Table 2.1 for patenting activity), and their matching success rate shows great volatility over the time period. In the other 11 countries the matching success rate increases over the time period. This attenuated success rate in early years is due to firms that have filed patent applications and subsequently gone out of business, and are therefore not alive in our period of observation for firms, which is 1995 to 2006. With a constant hazard rate of death this is more likely to happen the further back we go from the observation period. In many cases we can see a levelling off of the success rate in the latter part of the time period, that is, in years when the observed firm sample closely relates to the true population of registered firms. In a number of countries the success rate starts initially high, this simply reflects the fact that we successfully match the very few patents applied for in the early years of the EPO, which may have been disproportionately applied for by large firms that are more likely to survive until the firm observation period.

Table 2.3 shows the match results across countries for the entire time period, with the same ordering of countries by decreasing overall matching success (ordered by column 9). Column 2 shows the number of unique applicants responsible for the patent applications observed for each country (where a unique applicant is one with a unique ***standard name***). Column 3 shows the number of these applicants that are corporate and column 4 shows the number of these corporate applicants that have been matched to firm accounts for each country. Column 5 shows this as a percentage, so for the United Kingdom we can see that we have matched 70 percent of corporate applicants by all matching methods at our disposal. This success rate is considerably lower for other countries. Column 6 shows the number of these matched applicants that have been matched to a unique company account in Amadeus (or have been matched to multiple accounts in the first instance but resolved by one of the methods described in Section 2.2.3) and column 7 shows the percentage of corporate applicants that have been matched uniquely. Column 8 shows the percentage of corporate applicants matched weighted by their patent applications, and column 9 shows the same figure for unique matches and constitutes our key measure of success. The higher weighted success rates indicates that the matching process in disproportionately more successful at matching large patenting firms than small ones. This is in part likely due to higher survival rates for large firms that file patents in early years and is in part likely due to a deliberate effort in the manual matching phase of the process to ensure that large patenting firms are matched. The weighted unique success rate is over 50 percent for 12 of the 15 countries in the sample, and over 70 percent for 7 of the countries.

Table 2.3: Applicants for EPO patents filed 1978-2004 matched to Amadeus firms from 1996-2006

Country	No. of Applicants	No. of Corporate Applicants	No. Matched	% Matched (4)/(3)	No. Matched Uniquely	% Matched Uniquely (6)/(3)	Weighted % Matched *w**(4)/(3)	Weighted % Matched Uniquely *w**(6)/(3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
UK	21,950	14,495	10,196	0.70	10,089	0.70	0.88	0.88
DE	48,486	26,814	14,856	0.55	14,153	0.53	0.88	0.86
NL	7,693	5,382	2,445	0.45	2,395	0.45	0.86	0.85
FI	3,117	1,996	1,178	0.59	1,034	0.52	0.84	0.78
SE	9,315	5,238	2,537	0.48	2,516	0.48	0.75	0.75
BE	3,723	2,129	1,103	0.52	1,031	0.48	0.75	0.73
NO	2,241	1,283	788	0.61	751	0.59	0.73	0.72
ES	4,338	2,434	1,264	0.52	1,255	0.52	0.69	0.68
DK	3,653	2,363	1,277	0.54	1,259	0.53	0.76	0.63
IT	18,918	12,577	6,590	0.52	5,647	0.45	0.65	0.60
FR	26,460	15,184	5,523	0.36	4,980	0.33	0.60	0.57
CZ	370	182	80	0.44	78	0.43	0.54	0.53
PL	465	243	75	0.31	73	0.30	0.47	0.47
PT	296	165	60	0.36	59	0.36	0.46	0.46
GR	637	148	37	0.25	35	0.24	0.28	0.26

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, PT - Portugal. (2) The number of unique standardised applicant/proprietor names. (3) The number of applicant/proprietors that we have identified as corporates (not university, individual or government department). (4) Number of corporate applicants which we have matched to one or more entries in Amadeus

(5) The percentage of corporate applicants which we have matched to one or more entries in Amadeus. (6) Number of corporate applicants which we have matched to only one entry in Amadeus. (7) The percentage of corporate applicants which we have matched to only one entry in Amadeus. (8) The percentage of corporate applicants which we have matched to one or more entries in Amadeus, weighted by the applicant's total number of patents. (9) The percentage of corporate applicants which we have matched to only one entry in Amadeus, weighted by the applicant's total number of patents.

Our most successfully matched country is the United Kingdom with a weighted unique success rate of 88 percent. This number compares favourably with the results in Figure 19 of Hall, Jaffe and Trajtenberg (2001), which shows the percentage of patents matched to Compustat in the NBER data by grant year. Given that Compustat contains US firms the equivalent success rate is for US-assigned patents. This is less than 70 percent for all grant years, peaking in the late 1980s and declining below 50 percent by 1999 (since the Compustat firms are those existing in 1989). Our success rates are higher as we have a larger target population of firms, as Amadeus contains accounts for both listed and unlisted firms, whereas Compustat contains accounts for only listed firms.

Table 2.4 breaks down uniquely matched corporate applicants from (column 2 of Table 2.4 corresponds to column 6 of Table 2.3) into the method by which they have been matched, weighted by the applicant's proportion of patents held out of *matched* patents. For example, for the UK, 84 percent (column 4) of those matched did so on standard name, 7 percent (column 6) did so on stem name, 8 percent (column 8) on old name (only available for the UK), and a very small percentage were manually matched, 13 firms (column 9). Column 11 shows the number of applicants, from all methods, that matched to dropped or inactive firms, and we can see that this is a large proportion, 18 percent weighted by patents for the UK, which illustrate the importance of the use of old versions of Amadeus. The pattern is similar for nearly all countries in that the majority of matches are achieved using ***standard name***, although Belgium is a noted exception, with most matches there achieved using ***stem name***. The proportion of applicants that match to dead or inactive firms varies significantly across countries and is very high in some countries, 75 percent in Germany for example. Firms become "inactive" in Amadeus if they fail to file accounts for the most recent year, therefore it is an indication of accounting activity and is not an indication that the firm has ceased trading or other activities.[20]

[20] It is likely used in Germany to distinguish duplicate records in Amadeus, as discussed in section 2.2.3.

Table 2.4: Relative importance of each match method for *uniquely matched corporate applicants*

All		Standard Name		Stem Name		Previous Name		Manual Match		Of Which, Dead or Inactive	
Country	No. of Applicants Matched Uniquely	No. by this method	As weighted % of matches *w**(3)/(2)	No. by this method	As weighted % of matches *w**(5)/(2)	No. by this method	As weighted % of matches *w**(7)/(2)	No. by this method	As weighted % of matches *w**(9)/(2)	No. of applicants that Matched to Dead Firms	As weighted % of matches *w**(11)/(2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
UK	10,089	8819	0.84	424	0.07	833	0.08	13	0.01	2184	0.18
DE	14,153	13001	0.71	1139	0.02	0	0	13	0.02	6853	0.75
NL	2,395	2284	0.91	88	0.01	0	0	23	0.08	445	0.07
FI	1,034	888	0.77	144	0.20	0	0	2	0.03	294	0.70
SE	2,516	2429	0.71	74	0.01	0	0	13	0.28	165	0.04
BE	1,031	275	0.38	753	0.61	0	0	3	0.02	436	0.56
NO	751	681	0.82	67	0.13	0	0	3	0.05	111	0.08
ES	1,255	1188	0.89	54	0.05	0	0	13	0.06	131	0.10
DK	1,259	1115	0.88	133	0.05	0	0	11	0.03	176	0.05
IT	5,647	4333	0.64	1295	0.22	0	0	19	0.14	601	0.16
FR	4,980	3726	0.76	1237	0.10	0	0	17	0.15	826	0.12
CZ	78	73	0.97	5	0.03	0	0	0	0.00	7	0.07
PL	73	65	0.88	2	0.01	0	0	6	0.11	2	0.02
PT	59	50	0.72	6	0.12	0	0	3	0.17	3	0.02
GR	35	30	0.88	5	0.12	0	0	0	0.00	2	0.07

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, BG: Bulgaria, PT-Portugal. (2) Number of applicants matched to only one entry in Amadeus (as in col (6) of Table 1). (3) The number of applicants matched using a standardised version of the name. (4) The percentage of all matches that matched using a standardised version of the name, weighted by applicant's patents relative to matched patents. (5) The number of applicants matched using a stem version of the name. (6) The percentage of all matches that matched using a stem version of the name, weighted by applicant's patents relative to matched patents. (7) The number of applicants matched using a previous version of the firms name (from FAME). (8) The percentage of all matches that matched using a previous version of the firm's name, weighted by applicant's patents relative to matched patents. (9) The number of applicants matched by hand. (10) The percentage of all matches that matched by hand, weighted by applicant's patents relative to matched patents. (11) The number of applicants matched, by any method, to a dead or inactive firm. (12) The percentage of all matches that resulted, by any method, to an applicant matched to a dead or inactive firm, weighted by the applicant's no. of patents relative to total no. of matched patents.

2.3.2. Outputs

This section describes the structure of the data produced by the matching process and will really only be of interest to those readers who are about to use the data.

The core relationship in the dataset created by the matching process is a link of unique EPO patent application numbers to Amadeus firm BVD numbers. This and supplementary information on name standardisation of both EPO applicants and Amadeus firms constitute the key outputs of matching. Table A4 lists the data variables in the three entities that contain this information (see Appendix). They are described in turn here.

1. Patent BVD match – this file contains a unique list if EPO patent application numbers and Amadeus firm BVD numbers. It can link to the Amadeus accounts database on **bvdidnumber** and **year** to match patent activity to accounts information for each firm-year (where for the patent, the year is the year of filing the patent application). Extra patent information, such as inventors, citations, grant status and technology class can be obtained by linking to the PATSTAT database on **appln_nr** (see European Patent Office 2006 for details on the information in PATSTAT). A basic measure of patent activity can be constructed by counting the number of unique patent applications filed each year by each unique BVD. Also included is the match_type variable which describes how the match was achieved (see Table A3 for a list of possible values).
2. Auxiliary Match File – this file contains all matched and unmatched **applicant_name** records, along with the match_type which defines how the match was achieved. The file also contains the standardised names for the applicants, number of patents and address information, and the applicant_type which identifies if the matching process identified the applicant as **non-corporate** (see Table A3 for a list of possible values). Where the applicant has matched to an Amadeus firm, the firm bvdidnumber, address information, activity status and ownership information is recorded. The purpose of this file is to give the researcher full information to judge the quality of the match.
3. Auxiliary Match File (Firms) – this file contains the full target population of Amadeus firms, i.e. all matched and unmatched firms. Also included is standardised name information and ownership data. This gives the researcher full information to

explore cases where patent applicants have not matched to firms that the researcher may be particularly concerned about. The uo variable holds the BVD of the ultimate owner as created by Amadeus, the buo variable holds the BVD of the ultimate owner identified using CEP's ownership algorithm (see Belenzon 2007).

3. THE MATCHED DATASET

This section has two purposes. The first is to further validate the data through: i) the description of patterns of patenting in the data, ensuring that they are intuitive; and ii) the comparison of our dataset with R&D expenditure. Section 3.1 will describe industry patterns of patenting and section 3.2 will describe country patterns of patenting and specialisation. The second purpose is to describe the dataset, investigating: i) how it relates to stylised facts concerning firm size and patenting (section 3.3); and ii) what it tells us about the scientific complexity of innovation in industries and how this relates to the concentration of patenting among firms (section 3.4).

3.1. Industry Patterns

Table 3.1 provides a summary of the resulting dataset, with total patent applications between the years 1995 and 2002 summarised by country and two digit industry category for all firms. The total number of patents applied for in this period by matched corporations equals 236,935. Of these, 161,478 were applied for by firms operating in manufacturing and 73,324 by firms operating in services (see final column of Table 3.1). Within manufacturing the five most prolific sectors in our sample are: Machinery and Equipment (25,717 applications); Chemicals, excluding pharmaceuticals (23,022 applications); Electrical Machinery and Apparatus (20,547 applications); Motor Vehicles, Trailers and Semi-Trailers (20,303 applications); and Radio, Television and Communication Equipment (19,880 applications). Pharmaceuticals (11,619 applications) and Medical, Precision and Optical Instruments (10,300 applications) are sixth and seventh highest respectively.

Table 3.1: Country-Industry Breakdown of Matched Patent Applications 1995-2002

Industry	Country														
	BE	CZ	DK	FI	FR	DE	GR	IT	NL	NO	PO	PT	ES	SE	UK	**Sector Totals**
AGRICULTURE, HUNTING AND FORESTRY	0		6		7	10	1	0	21	0		1	5	3	53	107
FISHING					1					4				1	4	10
MINING AND QUARRYING		1	0		15	37		81	97	335			9	1	256	832
Agriculture and Mining sub-totals	**0**	**1**	**6**	**0**	**23**	**47**	**1**	**81**	**118**	**339**	**0**	**1**	**14**	**5**	**313**	**949**
FOOD PRODUCTS, BEVERAGES AND TOBACCO	40	1	36	39	71	221	3	113	1733	9	1		20	11	1142	3440
TEXTILES	22	1	11	28	123	273	2	113	15	8	0		9	15	170	790
WEARING APPAREL, DRESSING AND DYEING OF FUR	1	0		1	22	65		24	0			0	4	3	14	134
LEATHER, LEATHER PRODUCTS AND FOOTWEAR			1	4	17	32		110	2	0			3	1	9	179
WOOD AND PRODUCTS OF WOOD AND CORK	1		4	7	33	172		51	8	3		3	14	48	14	358
PAPER AND PAPER PRODUCTS	75		25	86	146	305	0	37	34	4			16	394	146	1268
PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA	4		4	1	36	428		32	11	1		0	9	12	205	743
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	6			4	34	71		11	5				8	50	40	229
CHEMICALS EXCLUDING PHARMACEUTICALS	1578	1	496	144	4432	10083	0	682	1248	106	4	1	169	233	3845	23022
PHARMACEUTICALS	605	11	634	97	994	5422	7	474	104	134	6	10	221	1232	1668	11619
RUBBER AND PLASTICS PRODUCTS	282	2	58	25	702	2408	3	667	138	21	1	16	83	131	576	5113
OTHER NON-METALLIC MINERAL PRODUCTS	119	3	17	65	297	1023		148	32	7			22	21	199	1953
BASIC METALS	289	0	2	12	297	982	1	129	90	2	0	0	38	127	122	2091
FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT	47	7	64	93	726	3699		744	197	26	0	3	108	212	1374	7300
MACHINERY AND EQUIPMENT, NEC	497	19	544	919	1549	15551	9	2724	757	154	1	1	281	930	1781	25717
OFFICE, ACCOUNTING AND COMPUTING MACHINERY	12		8	3	251	321		83	207	25			2	83	285	1280

ELECTRICAL MACHINERY AND APPARATUS, NEC	79	2	97	77	1639	6283		1017	10123	20	2	1	147	59	1001	20547
RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	67		35	4572	1749	12065	1	213	61	16			23	79	999	19880
MEDICAL, PRECISION AND OPTICAL INSTRUMENTS, WATCHES AND CLOCKS	102	2	405	313	1803	4793	1	540	312	71	3	2	45	803	1105	10300
MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	21	24	4	26	2202	16064	0	516	126	13	3	6	127	489	682	20303
OTHER TRANSPORT EQUIPMENT	76	0	9	20	521	1071		128	269	35	4	1	42	160	177	2513
MANUFACTURING NEC	32		18	18	484	783	0	345	23	49	1		31	47	868	2699
Manufacturing sub-totals	**3,955**	**73**	**2,472**	**6,554**	**18,128**	**82,115**	**27**	**8,901**	**15,495**	**704**	**26**	**44**	**1,422**	**5,140**	**16,422**	**161,478**
ELECTRICITY, GAS AND WATER SUPPLY	2		2	7	6	111		22	19	4		1	14	22	105	315
CONSTRUCTION	24	0	10	33	318	1069		114	70	7	0		9	27	449	2130
WHOLESALE AND RETAIL TRADE; RESTAURANTS AND HOTELS	180	5	225	102	1291	12720	1	1314	500	51	3	23	248	721	757	18141
TRANSPORT AND STORAGE AND COMMUNICATION	7		32	169	901	763		271	350	19	1		40	286	1318	4157
FINANCE, INSURANCE, REAL ESTATE AND BUSINESS SERVICES	601	16	1344	1012	11283	14182	4	1390	4100	522	14	15	306	7233	6559	48581
Services sub-totals	**814**	**21**	**1,613**	**1,323**	**13,799**	**28,845**	**5**	**3,111**	**5,039**	**603**	**18**	**39**	**617**	**8,289**	**9,188**	**73,324**
PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY				3		4									6	13
EDUCATION	5		1		2	60		0	0		3	1		6	12	90
HEALTH AND SOCIAL WORK	16	1	3	1	0	73		4	34	2			23	10	167	334
OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	13	0	3	23	42	284		18	19	3		0	5	10	326	746
PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS															0	0
EXTRA-TERRITORIAL ORGANISATIONS AND BODIES															1	1
Public sector sub-totals	**34**	**1**	**7**	**27**	**44**	**421**	**0**	**22**	**53**	**5**	**3**	**1**	**28**	**26**	**512**	**1,184**
Country Totals	**4,803**	**96**	**4,098**	**7,904**	**31,994**	**111,428**	**33**	**12,115**	**20,705**	**1,651**	**47**	**85**	**2,081**	**13,460**	**26,435**	**236,935**

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, PT - Portugal. Four patents are excluded as they match to firms with invalid sector codes.

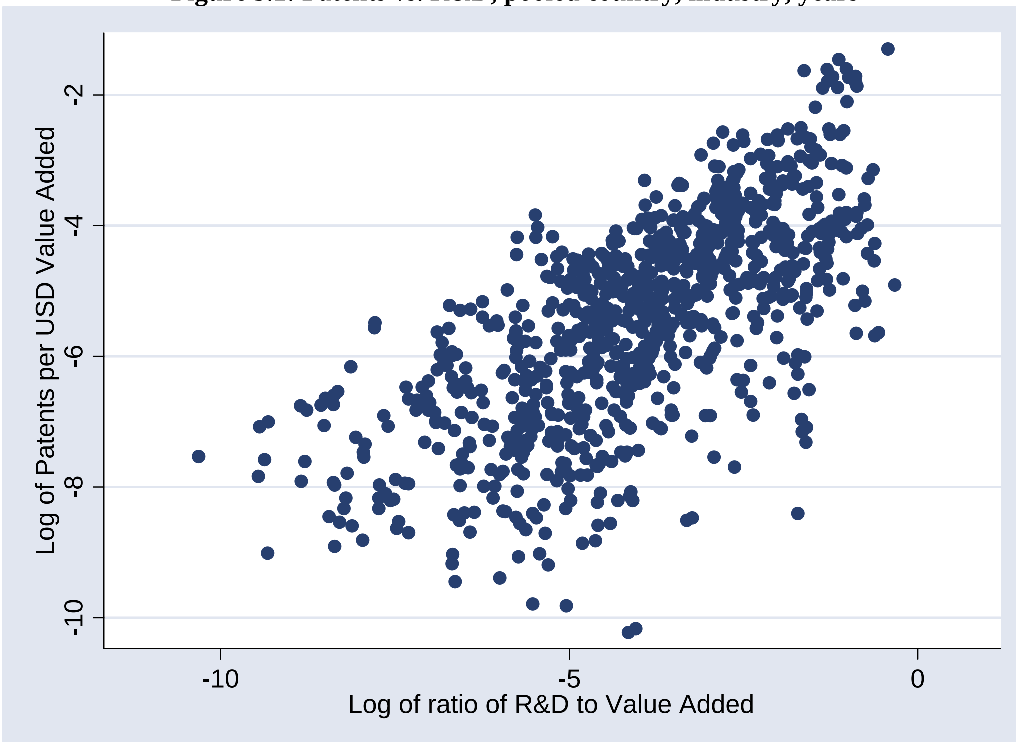
These rankings could just reflect that some industries are larger than others. Column 1 of Table 3.2 shows the sectors ranked by the cross-country average of patent applications per US dollar of value added. The sectors just listed, with the addition of Office, Accounting and Computing Machinery, constitute the eight most patent intensive industries.

Table 3.2: Manufacturing Industries Ranked by Patent Intensity

Industry	Patents per million USD Value Added (1)	R&D as proportion of Value Added (2)
RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	0.059	0.274
PHARMACEUTICALS	0.047	0.273
CHEMICALS EXCLUDING PHAMACEUTICALS	0.044	0.067
MEDICAL, PRECISION AND OPTICAL INSTRUMENTS, WATCHES AND CLOCKS	0.044	0.115
OFFICE, ACCOUNTING AND COMPUTING MACHINERY	0.027	0.311
MACHINERY AND EQUIPMENT, NEC	0.023	0.059
ELECTRICAL MACHINERY AND APPARATUS, NEC	0.016	0.064
MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	0.014	0.088
RUBBER AND PLASTICS PRODUCTS	0.011	0.029
OTHER TRANSPORT EQUIPMENT	0.009	0.147
FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT	0.007	0.011
MANUFACTURING NEC	0.006	0.011
TEXTILES	0.006	0.017
OTHER NON-METALLIC MINERAL PRODUCTS	0.004	0.015
PAPER AND PAPER PRODUCTS	0.004	0.037
FOOD PRODUCTS, BEVERAGES AND TOBACCO	0.004	0.013
BASIC METALS	0.004	0.025
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	0.003	0.038
LEATHER, LEATHER PRODUCTS AND FOOTWEAR	0.002	0.005
WOOD AND PRODUCTS OF WOOD AND CORK	0.001	0.004
WEARING APPAREL, DRESSING AND DYEING OF FUR	0.001	0.006
PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA	0.001	0.002

A standard measure of innovation at the 2-digit industry level is R&D expenditure from the OECD's Analytical Business Enterprise Research and Development database (see OECD 2006, OECD 2002). This data has been widely used in economic research and it is important to check that our dataset broadly agrees with it. Figure 3.1 shows the relationship between log patents per dollar value added and log R&D expenditure as a proportion of value added, for country-industry-year observations for private sector industries.

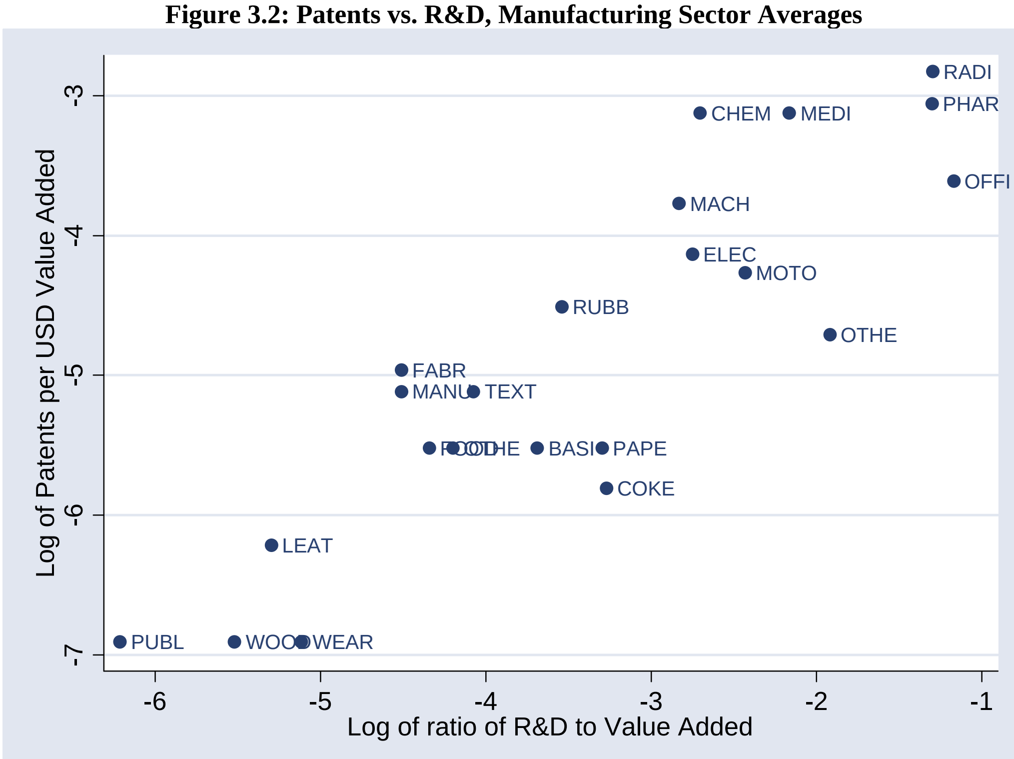
Figure 3.1: Patents vs. R&D, pooled country, industry, years



Notes: Observations are country-industry-years for 1995-2000 for private sector industries.

This is comparable to the Figure 2.4 of Bound et al. (1984) for US firm level data. Clearly there is a strong positive association between the two measures of innovation, with some suggestion of an increasing elasticity of patents to R&D for more innovative sectors, as in Bound et al. (1984) for more innovative firms. Running an OLS regression of log patents on log R&D, for all observations for which R&D expenditure is available, with log patents set to zero for observations with zero patents and log R&D set to zero and separate dummy variables included to indicate both zero patents and zero R&D, plus a full set of country, industry and time dummy variables, yields an estimated elasticity of patents with respect to R&D (robust standard error) of 0.33 (0.03). This compares favourably with the Bound et al. (1984) estimate, from running the same regression at the firm level, of 0.38 (see Bound et al. 1984, column 1 of Table 2.8). Naturally there is quite a difference between running such regressions at the firm level and running at the industry level, however it is reassuring that the estimate from our new dataset is not radically different from existing estimates. When we include a squared log R&D term in our regression we see that it is positive and significant, suggesting that the elasticity of patents with respect to R&D increases with R&D, as in Bound et al. (1984). Modelling the observations with zero patents explicitly by running a Poisson regression of patents on the log of R&D, again with country, industry and year dummies, yields a higher estimate of the elasticity of 0.50 (0.07), which may be due to the fact that Poisson regressions give higher weight to large observations, where the elasticity may indeed be higher. Again, if we include a squared log R&D term we find it positive and significant.[21] Returning to Table 3.2, column 2 shows the average R&D intensity for each sector. Figure 3.2 shows graphically that for these manufacturing sectors the two measures of innovation intensity are in broad agreement. Although the exact ordering might differ the two measures appear to consistently group the sectors into high, medium and low intensities. Furthermore the ordering is as we would expect, with high tech, heavy manufacturing sectors being more intensive and low tech, light manufacturing sectors being less intensive.

Figure 3.2: Patents vs. R&D, Manufacturing Sector Averages



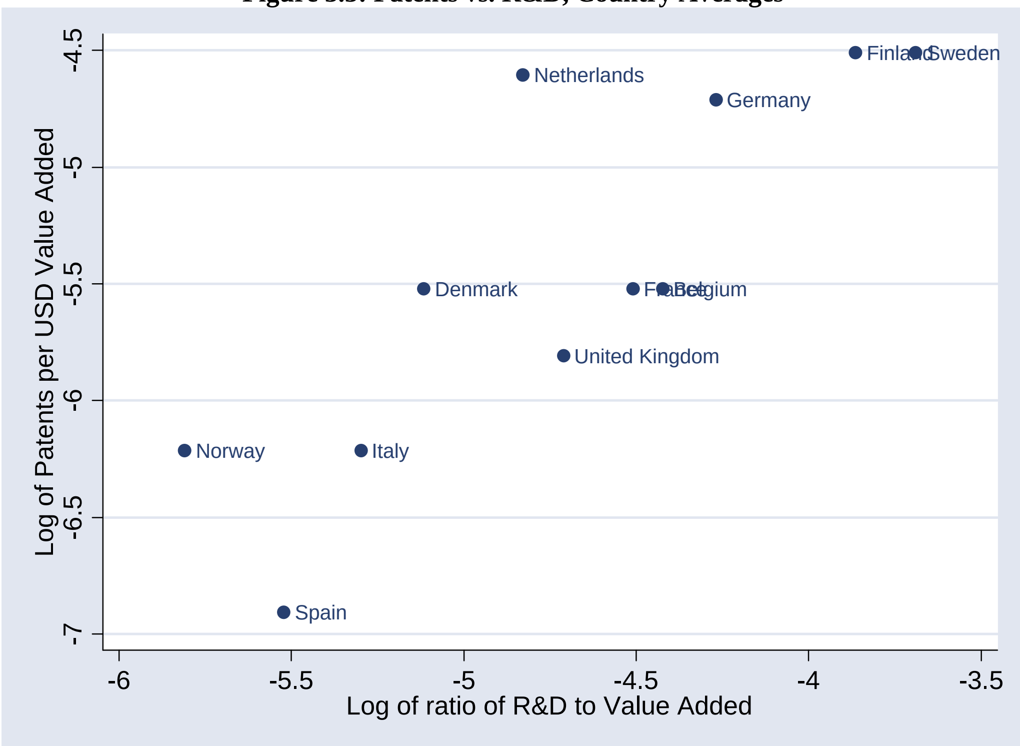
Notes: Values are natural logs of unweighted averages across countries.

[21] Figure 3.1 is based on the 931 observation with both patents and R&D greater than zero. The regressions referred to in the text are based on 1426 observations, with zero observations handled as described.

3.2. Country Patterns

Figure 3.3 shows that calculating (weighted) country averages of the two measures of innovation intensity, using all private sectors, yields an ordering that is consistent across the two measures. Finland, Sweden and Germany are ranked as highly innovative countries by both measures, Spain, Norway and Italy are low innovation countries by both measures, with Denmark, France, Belgium and United Kingdom making up an intermediary group. The Netherlands is among the most innovative countries when measured using patents, but in the intermediary group when measured using R&D. This is due to the presence of Phillips, a very high patenting company which is solely responsible for two thirds of all Dutch manufacturing patents.

Figure 3.3: Patents vs. R&D, Country Averages

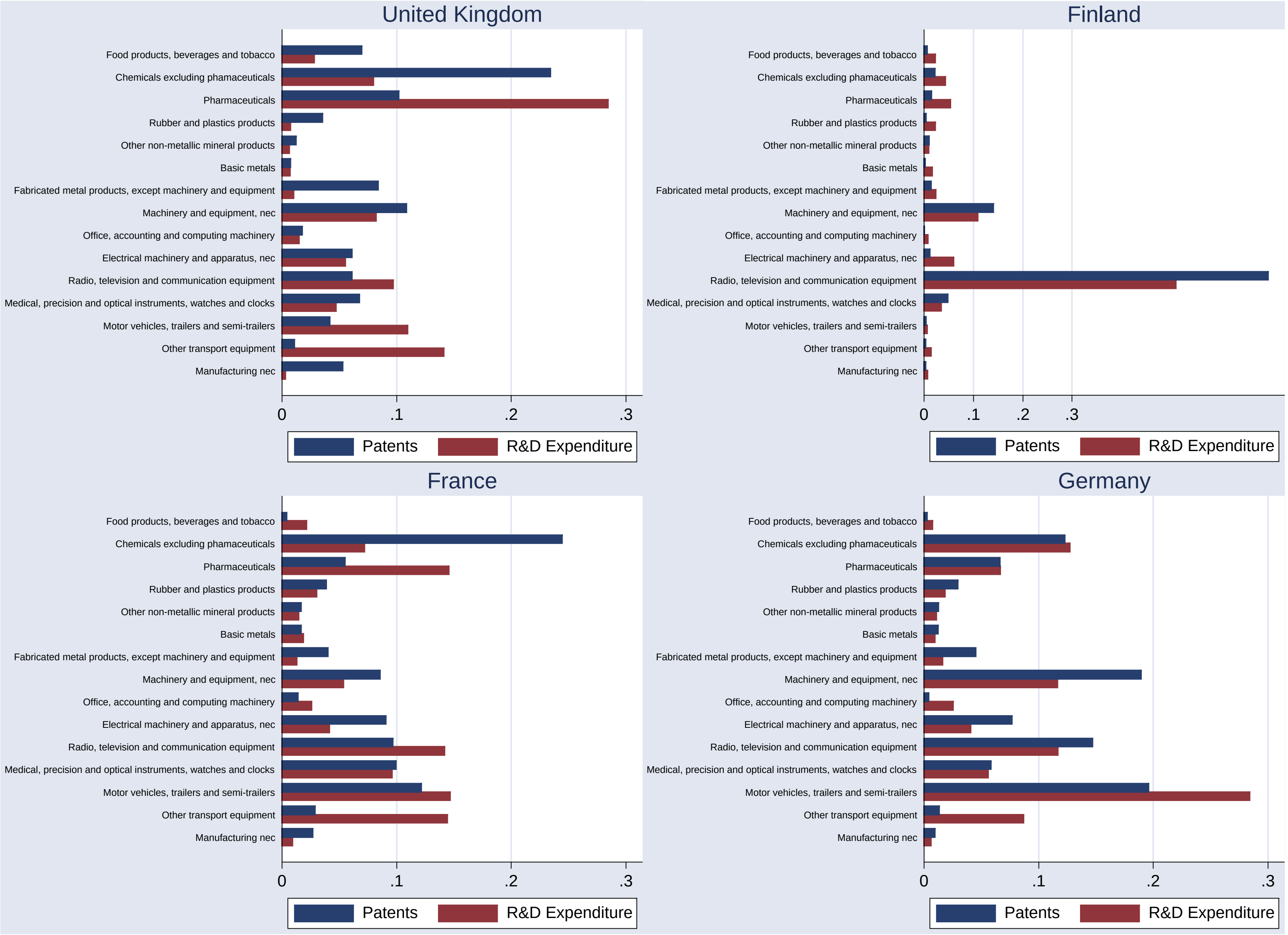


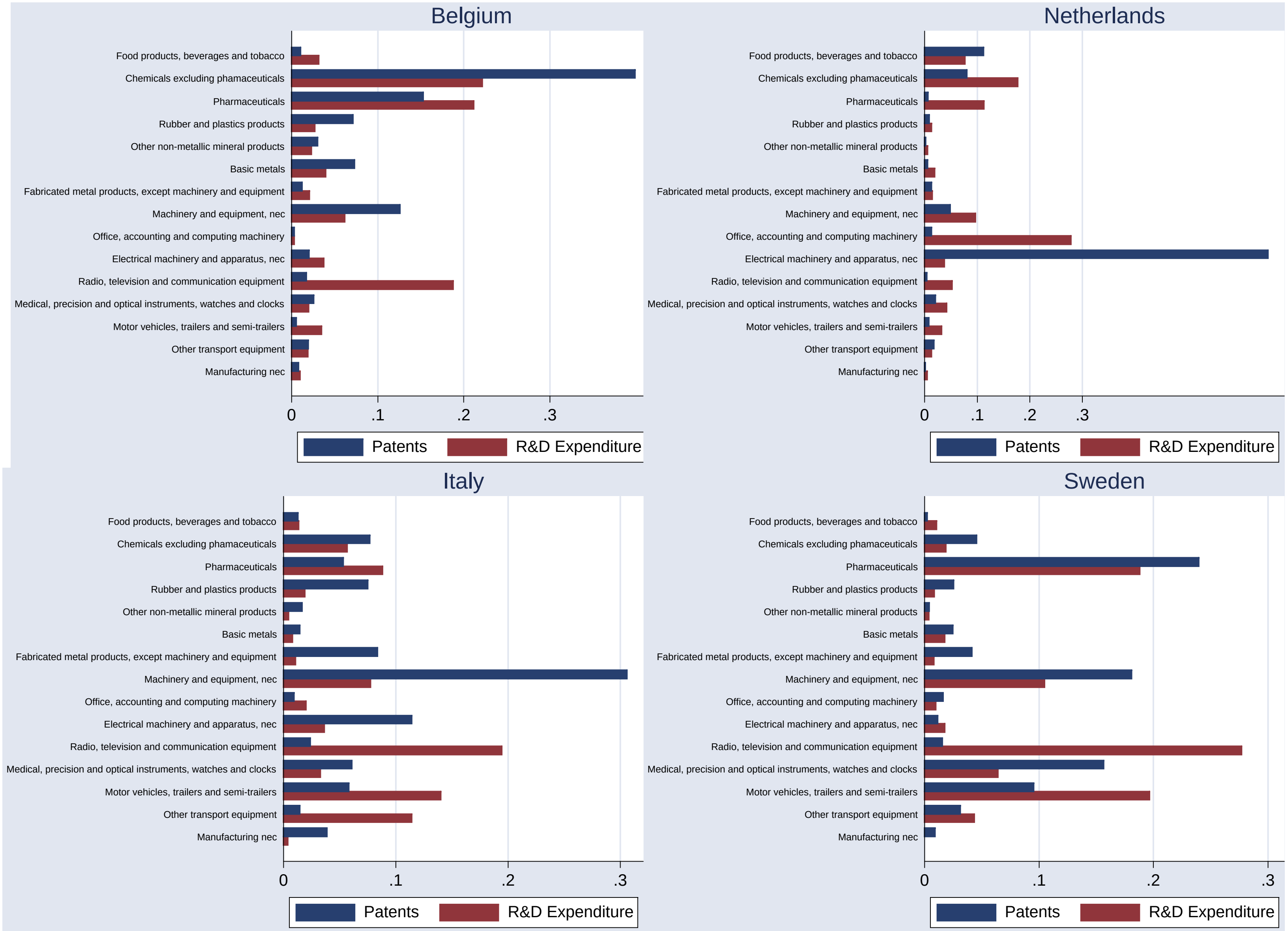
Notes: Values are natural logs of weighted averages across all private sectors.

Within countries matching error should be randomly distributed across industries for the time period under study. The patent measure should, therefore, give a reasonable picture of specialisation, one that should relate to an equivalent R&D measure. Figure 3.4 shows graphs for eleven of the countries in our sample of cross-industry specialisation as measured by patenting and as measured by R&D expenditure. The measures used are the total patent applications (R&D expenditure) in country *i* manufacturing industry *j* over the period 1995-2000 divided by the total patent applications (R&D expenditure) in country *i* over the period 1995-2000.[22][23] There is some concern in comparing across industries in this fashion in that the propensity to patent/cost of innovation varies across industries, and we would therefore expect some diversion of our two measures of innovation. Nevertheless we would expect that if our dataset is useful in measuring industry innovation there should be a strong positive correlation within countries across industries between the patent measure and the R&D measure. By inspection we can see this strong correlation for the countries in our sample and the correlation coefficient is 0.5901 for the 236 observations. The patterns observed here are consistent with some intuition and existing evidence we have on country innovation specialisation. For example, Germany's highest innovation manufacturing sector by both measures is motor vehicles, consistent with the view that Germany specialises in traditional manufacturing sectors (see Carlin and Mayer 2003), whereas the UK's highest innovation sector by patenting is chemicals and by expenditure is a pharmaceuticals. Also, we can see that Finland has a very strong specialisation by both measures in telecoms as we would expect. One discrepancy is the large spike in patenting activity in Electrical Machinery and Apparatus, nec, in the Netherlands. This is the result of very high patent filings by Phillips, which filed 1,445 of the 2,957 matched corporate patents in 2000. This highlights an important concern with using patent data, in that the distribution of patenting across firms is very highly skewed that it affects inference in applications that do not explicitly control for firm heterogeneity. Extreme outliers like this can lead to spurious results and it is common in the patent literature to control for such outliers or exclude the top percentile of the patent distribution, the justification being that the economic model under consideration cannot explain such uncommon patenting behaviour.

[22] The total number of patents filed by manufacturing firms in these 11 countries in our dataset between 1995 and 2000 equals 110,847.
[23] For presentational purposes the seven lowest manufacturing industries have been excluded from the graphs, although they are present in the measures. They are SIC's 17 to 23. For similar reasons I have focused on manufacturing, the same comparison could be performed for service sectors.

Figure 3.4: Industry Specialisation, Patents vs. R&D




Belgium
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
.2
.3
Patents
R&D Expenditure
Netherlands
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
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.3
Patents
R&D Expenditure
Italy
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
.2
.3
Patents
R&D Expenditure
Sweden
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
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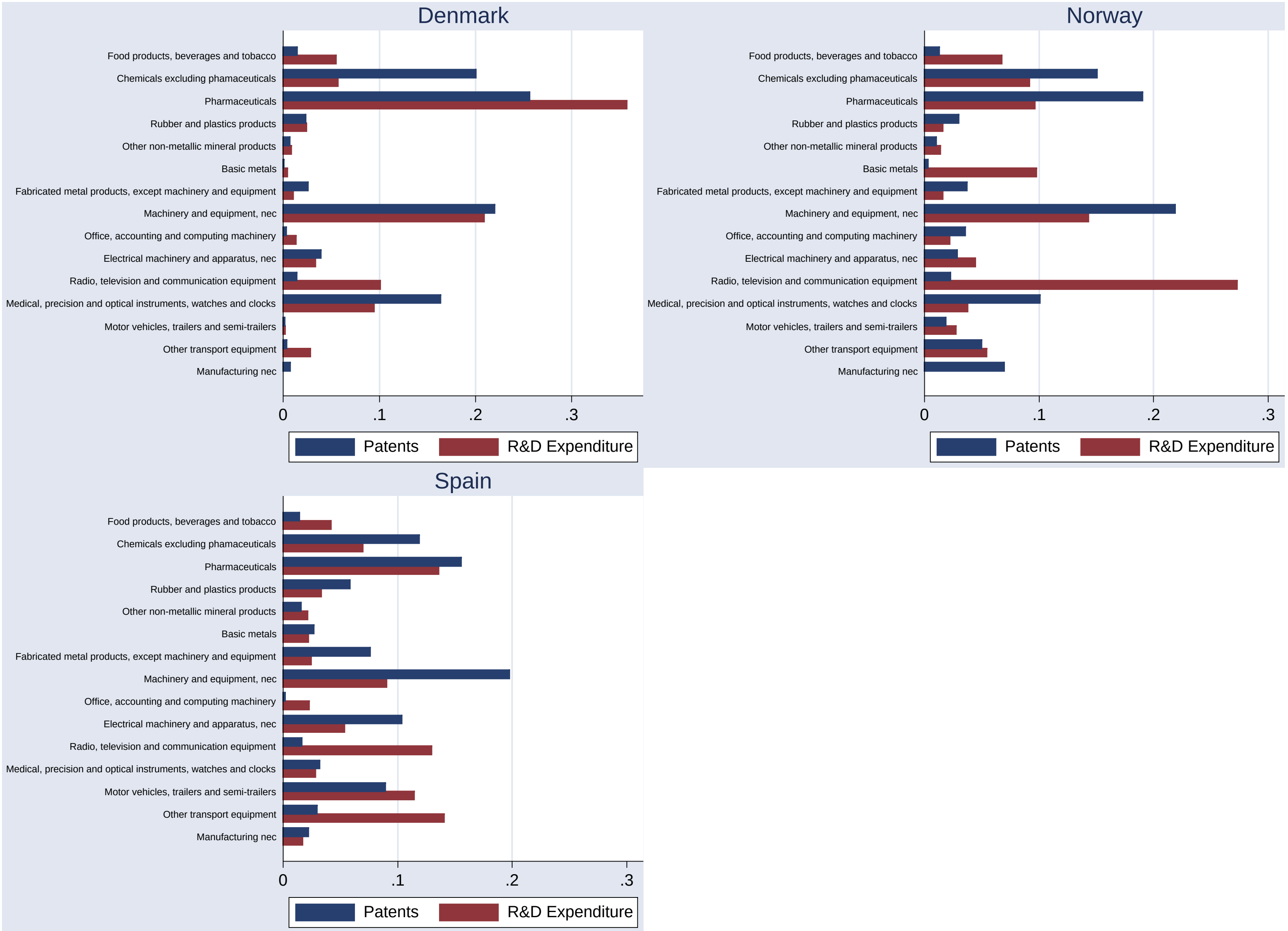
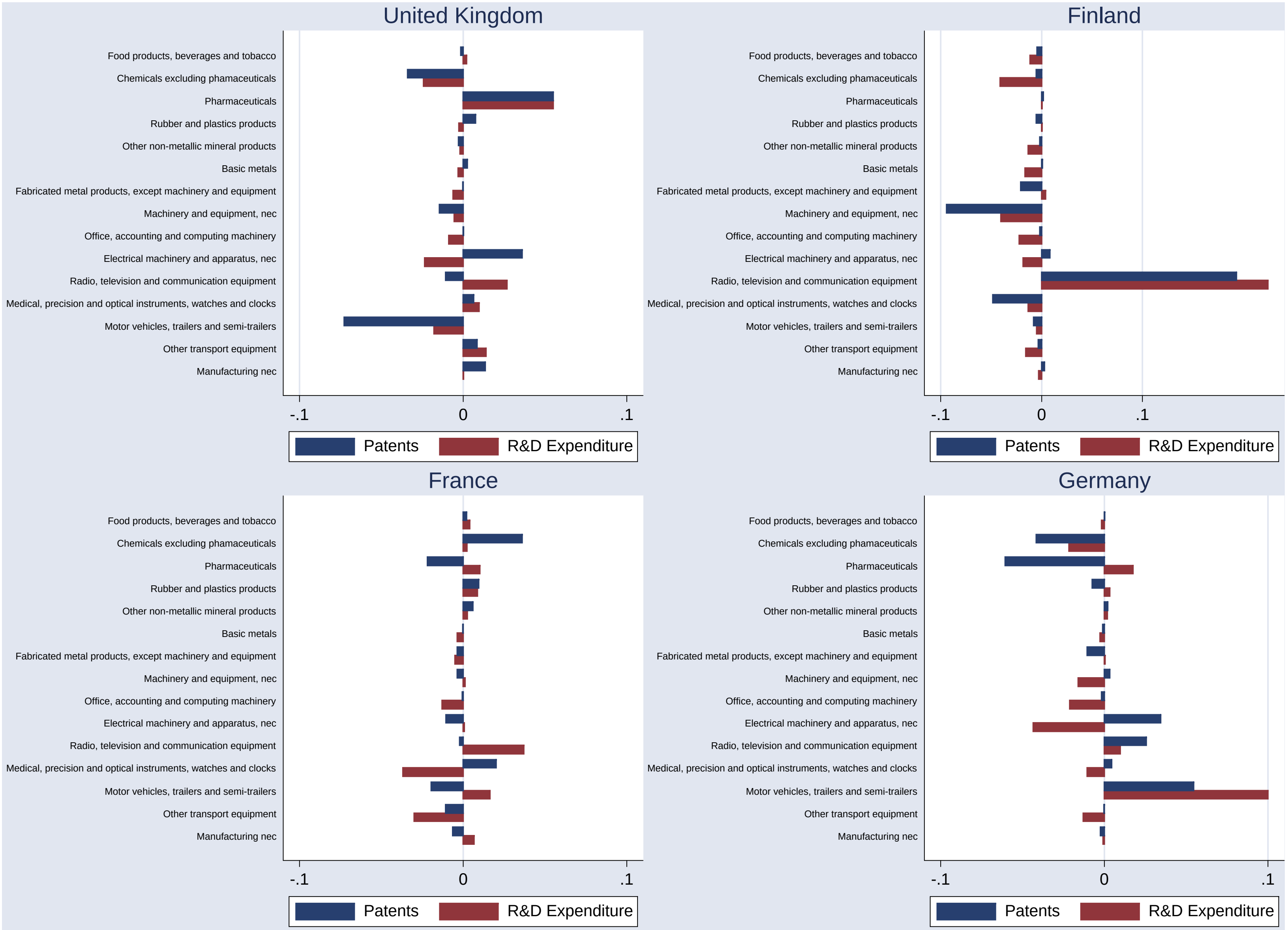
Patents
R&D Expenditure

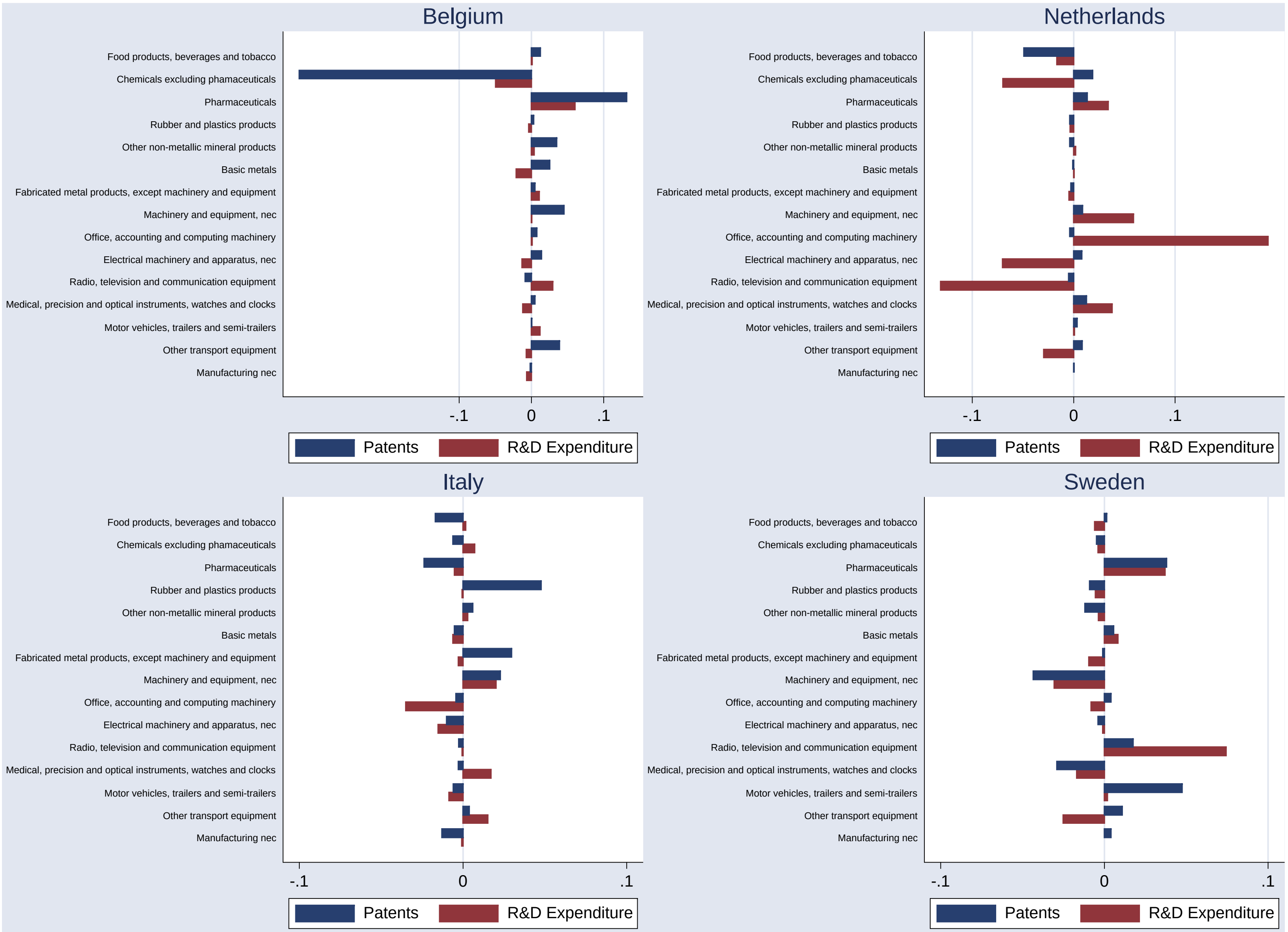

Denmark
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
.2
.3
Patents
R&D Expenditure
Norway
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
.2
.3
Patents
R&D Expenditure
Spain
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
0
.1
.2
.3
Patents
R&D Expenditure

Often in research applications identification is achieved through the use of within country, within industry variation over time to control for correlation from unobserved cross country and cross industry characteristics. It is therefore interesting to investigate if changes over time of country-industry patenting are correlated with changes in R&D expenditure. Figure 3.5 shows for each country the change in the proportion of country *i*'s patenting (R&D expenditure) in industry *j* between 1995 and 2000. There are issues of timing between patenting and R&D; Pakes and Griliches (1984) find that although there is a strong cross-sectional correlation between patents and R&D at the firm level, the relationship within firms over time is much weaker: patents seem to be applied for early on in R&D projects, but much of the R&D spend comes later, in the development phase (Griliches 1990). Nevertheless, we can see that there are many strong correlations particularly in heavy patenting industries such as chemicals, pharmaceuticals, communications, machinery, motor vehicles and other transport. Over all of the manufacturing sectors the correlation coefficient for changes in industry innovation specialisation as measured by patenting and as measured by R&D expenditure is 0.3844 for the 213 observations (this is less observations than before as the panel is unbalanced, some countries lack observations for certain industries in earlier years).

This section has shown that the matched patents dataset at an aggregate industry level is closely related to a often used measure of innovation in the form of declared R&D expenditure. The relationship between patents and R&D at the industry level is similar to that found in existing studies at the firm level from the United States. The matched patent dataset successfully ranks industries in groups of high, medium and low innovation intensity, and successfully ranks countries in groups of high, medium and low innovation intensity. Within countries the dataset measures industry specialisation in a manner highly correlated with a R&D based measure, however changes in specialisation over time are much less correlated with the equivalent changes as measured by R&D.

Figure 3.5: Changes in Industry Specialisation, Patents vs. R&D




Belgium
Netherlands
Italy
Sweden
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
-.1
0
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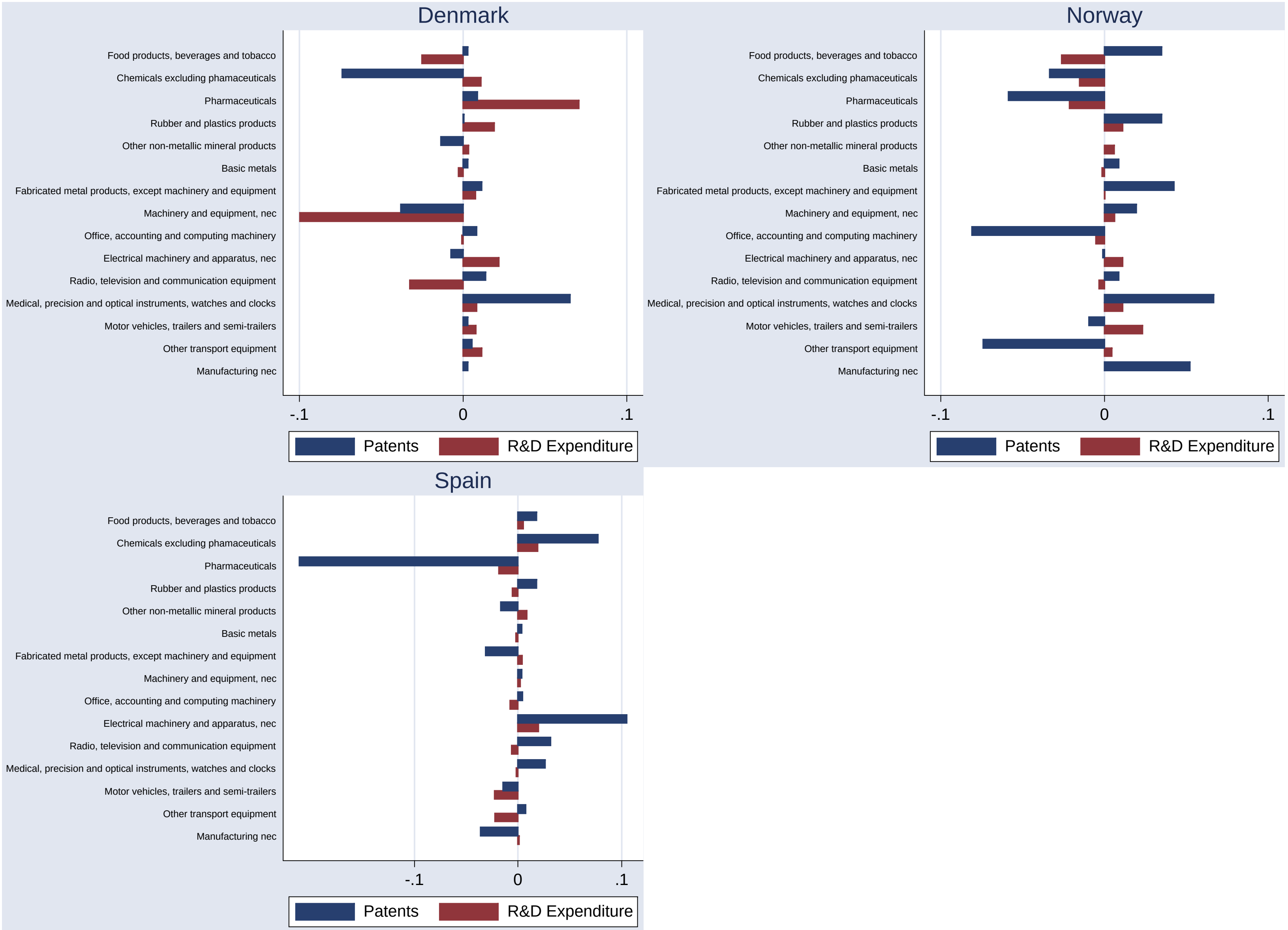
Patents
R&D Expenditure



Denmark
Norway
Spain
Food products, beverages and tobacco
Chemicals excluding phamaceuticals
Pharmaceuticals
Rubber and plastics products
Other non-metallic mineral products
Basic metals
Fabricated metal products, except machinery and equipment
Machinery and equipment, nec
Office, accounting and computing machinery
Electrical machinery and apparatus, nec
Radio, television and communication equipment
Medical, precision and optical instruments, watches and clocks
Motor vehicles, trailers and semi-trailers
Other transport equipment
Manufacturing nec
-.1
0
.1
Patents
R&D Expenditure

3.3. Patenting and Firm Size

This section investigates the relationship between the propensity to patent and firm size. Klepper and Cohen (1996) cites several stylised facts about the relationship between firm size and innovation. Two which we can investigate here are as follows:

Stylised fact 1: a higher proportion of large firms than small firms innovate (Klepper and Cohen 1996, stylised fact 1); and,

Stylised fact 2: conditioning on innovative firms patenting increases with firm size, although small firms account for a disproportionately large amount of patent applications (Klepper and Cohen 1996, stylised fact 4).

Consider the first of these existing observations. Table 2.4 of Bounds et al. (1984) also show that among US firms, large firms are more likely to report positive R&D, and this is supported by similar observations by Pavitt et al. (1987) for UK firms. We can investigate this in our sample, defining here patenting firms as those that patent between the years 1995 and 2002, excluding firms that are observed to patent only before this period as these will disproportionately be large firms, assuming that large firms have higher survival rates than small firms. In Table 3.3 we can see that this is also true for firms in each country in our dataset in that the percentage of firms that file patents increases with their position in the within country distribution of sales. For example, only 0.2 percent of UK firms (final column) in the bottom half of the size distribution apply for patents, whereas 3.6 percent do so between the 91st and 99th percentile of the distribution and 9.4 percent do so in the top percentile of the distribution. This pattern is common across all countries in the sample. There is a concern that the pattern may be an artefact of the matching process: in the manual stage of matching we deliberately target large firms for matching. The dataset enables us to exclude manual matches and resolved multiple matches, which also might favour large firms as they rely on supplementary data which may be more available for large firms. The numbers in italics in each cell in Table 3.3 show the fraction of firms in each size class that patent using only automated unique ***standard name*** and ***stem name*** matches (match types 1.1 and 1.2 in Table A3, other match types remain in the sample but are changed to non-patenting firms). Using just these match types we can see that the observation that a higher proportion of large firms patent remains: for the UK the equivalent values to those quoted above are 0.2 percent, 3.2 percent and 8.4 percent.

Turning to the second stylised fact described above, a number of studies find that for innovative firms inventive output increases with firm sales but at a less than proportionate rate, so that smaller firms account for a more than proportionate amount of innovation (Scherer 1965, Bound et al. 1964, Pavitt et al. 1987). This is true for all countries in our sample. Table 3.4 shows results of a Poisson regression of total patent applications on the log of average sales for all private sector firms that patent at least once in the period 1995-2002, with industry fixed effects controlling for cross industry differences in size and the propensity to patent. An elasticity of less than one, which is found for all countries, indicates that although patenting increases with sales it does so less than proportionately.

Table 3.3: Firm Size and the Propensity to Patent

Size Classification, by percentile in sales distribution within each country		Country										
		BE	DK	FI	FR	DE	IT	NL	NO	ES	SE	UK
1st-50th	No. of firms	79,375	18,034	31,045	318,571	268,834	107,247	10,374	65,305	295,211	97,730	212,800
	Fraction that patent	0.000	0.003	0.003	0.001	0.002	0.003	0.006	0.003	0.000	0.004	0.002
		0.000	*0.003*	*0.003*	*0.001*	*0.002*	*0.002*	*0.006*	*0.003*	*0.000*	*0.004*	*0.002*
51st-75th	No. of firms	39,751	9,033	15,537	159,240	134,332	53,510	5,142	32,683	147,778	48,883	106,466
	Fraction that patent	0.001	0.004	0.005	0.001	0.004	0.006	0.020	0.002	0.000	0.003	0.003
		0.001	*0.004*	*0.005*	*0.001*	*0.004*	*0.005*	*0.019*	*0.002*	*0.000*	*0.003*	*0.003*
76th-90th	No. of firms	23,783	5,404	9,281	95,434	80,122	31,915	3,066	19,592	88,552	29,268	63,541
	Fraction that patent	0.004	0.007	0.009	0.004	0.014	0.019	0.038	0.002	0.001	0.007	0.011
		0.003	*0.007*	*0.009*	*0.003*	*0.014*	*0.016*	*0.036*	*0.002*	*0.001*	*0.007*	*0.010*
91st-99th	No. of firms	14,182	3,194	5,558	56,909	47,358	18,928	1,837	11,732	53,025	17,391	37,643
	Fraction that patent	0.013	0.052	0.024	0.017	0.070	0.055	0.048	0.009	0.006	0.025	0.036
		0.005	*0.051*	*0.023*	*0.016*	*0.027*	*0.050*	*0.045*	*0.009*	*0.006*	*0.025*	*0.032*
100th	No. of firms	1,556	352	608	6,224	5,255	2,074	203	1,289	5,837	1,912	4,085
	Fraction that patent	0.058	0.119	0.043	0.102	0.147	0.120	0.143	0.050	0.039	0.113	0.094
		0.028	*0.111*	*0.041*	*0.096*	*0.065*	*0.111*	*0.133*	*0.050*	*0.038*	*0.112*	*0.084*
Sales N/A	No. of firms	158,593	118,264	21,740	190,542	306,420	227,049	324,891	43,633	222,466	40,977	1,353,240
	Fraction that patent	0.001	0.004	0.009	0.001	0.007	0.002	0.003	0.002	0.000	0.004	0.002
		0.001	*0.004*	*0.005*	*0.001*	*0.005*	*0.002*	*0.003*	*0.002*	*0.000*	*0.004*	*0.002*

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, PT - Portugal.(2) The fraction that patent is given calculated using all matches and using just automated unique matches (match types 1.1 and 1.2) in italics.

Table 3.4: Patenting and Firm Size, for patenting firms

Dependent variable:	Patent Applications										
	BE	DK	FI	FR	DE	IT	NL	NO	ES	SE	UK
Log Sales	0.6172	0.5498	0.7377	0.6617	0.7261	0.5516	0.9253	0.2275	0.2398	0.6442	0.4388
	[0.0617]	[0.0931]	[0.1134]	[0.0552]	[0.0389]	[0.0402]	[0.0785]	[0.0300]	[0.0346]	[0.1317]	[0.0359]
Constant	-2.4205	-1.4504	-0.5114	-1.4627	-8.9506	-6.7238	-0.6503	-0.2085	-0.8235	-0.5781	-1.4924
	[0.2418]	[0.3628]	[0.0786]	[0.1797]	[0.6640]	[0.6875]	[0.2071]	[0.0275]	[0.1189]	[0.3427]	[0.1222]
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	434	338	427	2444	6273	2516	386	428	747	1381	3032

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, PT - Portugal.(2) Observations are private sector firms all of which have patented at least once in the sample period of 1995-2002. Patents are summed over the period and Log Sales is the log of the average value of turnover in USD over the same period.(3) The regression run is a Poisson regression, therefore coefficients can be interpreted as elasticities. Robust standard errors are in brackets.

3.4. Scientific Complexity and Concentration

One advantage of the new dataset is that the patent dataset provides further information on the patents applied for, in the form of citations and inventor information. One use of this data is that it gives an idea of the complexity of innovation. Recorded in the PATSTAT dataset, as well as citation to other patents, is the count of citations to non-patent literature (NPL), predominantly scientific journals. We introduce here the proportion of citations made by a patent to NPL as a measure of the closeness of innovation to the scientific frontier.

Table 3.5 shows manufacturing sectors ordered by the average of the proportion of citations to NPL, column (1). Along with the rest of the variables in this table the un-weighted firm average is taken at the country, four digit industry level, and then the median of the distribution of those values is taken at the two-digit industry level, for ease of presentation in Table 3.5. The ordering of sectors by proportion of citations to NPL is as we might expect, with high tech sectors such as pharmaceuticals, communications and chemicals at the top of the table moving down to more traditional manufacturing sectors such as motor vehicles and machinery and equipment, down to lighter manufactures such as clothes and apparel. The average number of inventors per patent is displayed in column (2), as a measure of complexity. This is clearly highly correlated with the NPL measure of complexity (the correlation coefficient is 0.75). Product life-cycle theory (Klepper 1996) relates the nature of innovation to market structure, predicting that early life-cycle product markets experience both a large amount of new product innovation and entry, and that later life-cycle markets experience more process innovation and more innovation by incumbents rather than entrants. Breschi et al. (2000) define two main patterns of innovation in industries: a Schumpeter Mark I period of creative widening, with a disproportionate amount of innovation performed by entrants; and a Schumpeter Mark II period of creative deepening, with innovation concentrated in the hands of incumbent firms. Column 3 recreates one of the measures used by Breschi et al. (2000) to identify Schumpeter Mark I industries: the proportion of patents filed by firms patenting for the first time. By inspection this measure is clearly negatively correlated with the values in columns (1) and (2), the correlations coefficients of entry intensity to the proportion of citations to NPL and the average number of inventors per patent are respectively -0.53 and -0.62. Patenting in industries that are engaged in more scientifically complex innovation is more likely to be performed by incumbents than patenting in industries engaged in less scientifically complex innovation. Column 4 lists a Herfindahl concentration measure of patenting, which is weakly positively correlated with both column (1) and column (2), reinforcing the observation that highly technical patenting is concentrated in the hands of incumbent firms.

Table 3.5: Industry Patenting Characteristics in Manufacturing

Industry	Proportion of citation to NPL (1)	Average no. of inventors per patent (2)	Entry Intensity (3)	Concentration (patent HHI) (4)	Patents/Sales (5)
PHARMACEUTICALS	0.36	3.08	0.04	0.1700	12.44
RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	0.17	1.93	0.04	0.3600	15.43
CHEMICALS EXCLUDING PHAMACEUTICALS	0.15	2.54	0.03	0.5000	9.84
BASIC METALS	0.13	2.00	0.05	0.3900	2.39
OFFICE, ACCOUNTING AND COMPUTING MACHINERY	0.13	1.89	0.14	0.2700	3.70
OTHER TRANSPORT EQUIPMENT	0.11	2.00	0.04	0.3300	4.80
ELECTRICAL MACHINERY AND APPARATUS, NEC	0.10	1.74	0.14	0.1500	14.64
MEDICAL, PRECISION AND OPTICAL INSTRUMENTS, WATCHES AND CLOCKS	0.10	2.07	0.13	0.0900	26.97
MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	0.10	1.82	0.04	0.3400	10.09
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	0.09	3.00	0.00	0.3600	0.22
FOOD PRODUCTS, BEVERAGES AND TOBACCO	0.08	2.00	0.11	0.0000	0.22
RUBBER AND PLASTICS PRODUCTS	0.07	1.73	0.19	0.1300	11.12
MACHINERY AND EQUIPMENT, NEC	0.07	1.68	0.14	0.1800	16.32
PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA	0.06	1.89	0.12	0.3300	3.69
OTHER NON-METALLIC MINERAL PRODUCTS	0.06	1.83	0.25	0.3100	6.46
FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT	0.06	1.54	0.26	0.1400	11.81
MANUFACTURING NEC	0.06	1.64	0.27	0.0400	11.87
LEATHER, LEATHER PRODUCTS AND FOOTWEAR	0.05	1.43	0.36	0.1800	6.98
TEXTILES	0.04	1.50	0.22	0.2600	6.51
WOOD AND PRODUCTS OF WOOD AND CORK	0.03	1.33	0.50	0.1900	5.54
PAPER AND PAPER PRODUCTS	0.03	1.86	0.20	0.3300	3.91
WEARING APPAREL, DRESSING AND DYEING OF FUR	0.00	1.00	0.11	0.4100	1.31

Notes: (1) the proportion of citations to non-patent literature, calculated for each patent, averaged for each firm, averaged for each country-four digit industry, the median within each two-digit industry shown here. (2) calculated as in column 1 for number of inventors per patent. (3) the proportion of patent applications made by a first time patenter, average for each country-four digit industry, median of which taken for each two-digit industry show here. (4) Herfindahl index based on share of patents in country-four digit industry sector held by each firm, median of which taken for each two digit industry shown here. (5) Patents per sales (in thousands of USD), average at the country-four digit industry sector, median of which taken for each two digit industry shown here.

4. CONCLUSION

This paper has described the creation of a valuable new dataset of firm level measures of innovation by way of patent applications for a very large population of firms from 15 European countries. The authors contribution to the creation of this dataset was the matching of patent applicants at the EPO to company names in the accounting database Amadeus. This non-trivial task was carried out through the development of reusable corporate name standardization software and high success rates were achieved for the countries in the sample. Much remains to be done and it is envisaged that, as with other similar datasets, matching and data checking will be developed over time by the researchers who use the data. The current paper shows that the resulting dataset compares favourably to a widely used source of information on R&D expenditure at the industry level. The paper also shows that the dataset exhibits some of the relationships between patenting and firms size evident in existing datasets and research papers. The paper describes a measure of scientific complexity based on patent citations and how it varies across industries and how it is related to patenting concentration.

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APPENDIX

Table A1: Name Standardisation, additional to Derwent 2000 standard

Country	String	Changed to	Country	String	Changed to
UK	PUBLIC LIMITED COMPANY	PLC	FR	SOCIÉTÉ CIVILE	SC
UK	PUBLIC LIMITED CO	PLC	FR	SOCIETE EN NOM COLLECTIF	SNC
UK	PUBLIC LIMITED	PLC	FR	SOCIETE EN PARTICIPATION	SP
UK	PUBLIC LIABILITY COMPANY	PLC	FR	SOCIETE EN COMMANDITE SIMPLE	SCS
UK	COMPANY	CO	FR	SOCIETE PRIVEE A RESPONSABILITE LIMITEE	SPRL
UK	LIMITED	LTD	BE	SOCIETE ANONYME SIMPLIFIEE	SAS
UK	HOLDINGS	HLDGS	BE	SOCIETE ANONYME	SA
UK	HOLDING	HLDGS	BE	SOC ANONYME	SA
UK	CORPORATION	CORP	BE	STE ANONYME	SA
UK	INCORPORATED	INC	BE	SOCIETE A RESPONSABILITE LIMITEE	SARL
UK	INTERNATIONAL	INTL	BE	SOCIETE A RESPONSIBILITE LIMITEE	SARL
UK	UNITED KINGDOM	GB	BE	SARL UNIPERSONNELLE	SARLU
UK	UNITED KINGDOM	UK	BE	SOCIETE PAR ACTIONS SIMPLIFIEES	SAS
UK	LTD CO	CO LTD	BE	SAS UNIPERSONNELLE	SASU
ES	SOCIEDAD LIMITADA	SL	BE	ENTREPRISE UNIPERSONNELLE A RESPONSABILITE LIMITEE	EURL
ES	SOCIEDAD ANONIMA	SA	BE	ET COMPAGNIE	ETCIE
ES	SOCIEDAD EN COMMANDITA	SC	BE	COMPAGNIE	CIE
ES	SOCIEDAD REGULAR COLECTIVA	SRL	BE	SOCIETE CIVILE IMMOBILIERE	SCI
ES	SCOOP	SC	BE	GROUPEMENT D'INTERET ECONOMIQUE	GIE
IT	SOCIETÁ IN ACCOMANDITA PER AZIONI	SA	BE	SOCIETE CIVILE	SC
IT	SOCIETA IN ACCOMANDITA PER AZIONI	SA	BE	SOCIÉTÉ CIVILE	SC
IT	SAPA	SA	BE	SOCIETE EN NOM COLLECTIF	SNC

IT	SOCIETÁ IN ACCOMANDITA SEMPLICE	SAS	BE	SOCIETE EN PARTICIPATION	SP
IT	SOCIETA IN ACCOMANDITA SEMPLICE	SAS	BE	SOCIETE EN COMMANDITE SIMPLE	SCS
IT	SOCIETÀ IN NOME COLLETTIVO	SNC	BE	BESLOTEN VENNOOTSCHAP	BV
IT	SOCIETA IN NOME COLLETTIVO	SNC	BE	BESLOTEN VENNOOTSCHAP MET BEPERKTE AANSPRAKELIJKHEID	BVBA
IT	SOCIETÀ PER AZIONI	SPA	BE	COMMANDITAIRE VENNOOTSCHAP OP AANDELEN	CVA
IT	SOCIETA PER AZIONI	SPA	BE	GEWONE COMMANDITAIRE VENNOOTSCHAP	GCV
IT	SOCIETÀ A RESPONSABILITÀ LIMITATA	SRL	BE	NAAMLOZE VENNOOTSCHAP	NV
IT	SOCIETA A RESPONSABILITA LIMITATA	SRL	BE	SOCIETE EN COMMANDITE PAR ACTIONS	SCA
SE	AKTIEBOLAG	AB	BE	SOCIETE PRIVEE A RESPONSABILITE LIMITEE	SPRL
SE	AKTIEBOLAG	AB	BE	GCV	SCS
SE	AKTIEBOLAGET	AB	BE	NV	SA
SE	HANDELSBOLAG	HB	BE	BVBA	SPRL
SE	HANDELSBOLAG	HB	DK	ANDELSSELSKAB	AMBA
SE	HANDELSBOLAGET	HB	DK	ANPARTSSELSKAB	APS
SE	HANDELSBOLAGET	HB	DK	AKTIESELSKAP	AS
SE	KOMMANDITBOLAG	KB	DK	INTERESSENTSKAB	IS
SE	KOMMANDITBOLAG	KB	DK	KOMMANDITAKTIESELSKAB	KAS
SE	KOMMANDITBOLAGET	KB	DK	KOMMANDITSELSKAB	KS
SE	KOMMANDITBOLAGET	KB	NO	ANDELSLAG	AL
DE	GESELLSCHAFT MIT BESCHRANKTER HAFTUNG	GMBH	NO	ANSVARLIG SELSKAP	ANS
DE	AKTIEN GESELLSCHAFT	AG	NO	AKSJESELSKAP	AS
DE	AKTIENGESELLSCHAFT	AG	NO	ALLMENNAKSJESELSKAP	ASA
DE	KOMMANDITGESELLSCHAFT AUF AKTIEN	KGAA	NO	SELSKAP MED DELT ANSAR	DA
DE	KOMANDIT GESELLSCHAFT	KG	NO	KOMMANDITTSELSKAP	KS
DE	KOMANDITGESELLSCHAFT	KG	NL	BESLOTEN VENNOOTSCHAP	BV
DE	KOMMANDIT GESELLSCHAFT	KG	NL	COMMANDITAIRE VENNOOTSCHAP	CV
DE	KOMMANDITGESELLSCHAFT	KG	NL	COMMANDITAIRE VENNOOTSCHAP OP ANDELEN	CVOA
DE	EINGETRAGENE GENOSSENSCHAFT	EG	NL	NAAMLOZE VENNOOTSCHAP	NV
DE	GENOSSENSCHAFT	EG	NL	VENNOOTSCHAP ONDER FIRMA	VOF

DE	GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG	GMBH	FI	AKTIEBOLAG	AB
DE	GESELLSCHAFT MIT BESCHRANKTER HAFTUNG	GMBH	FI	PUBLIKT AKTIEBOLAG	APB
DE	GESELLSCHAFT MBH	GMBH	FI	KOMMANDITBOLAG	KB
DE	GESELLSCHAFT M B H	GMBH	FI	KOMMANDIITTIYHTIO	KY
DE	OFFENE HANDELS GESELLSCHAFT	OHG	FI	OSAKEYHTIO	OY
DE	GESMBH	GMBH	FI	JULKINEN OSAKEYHTIO	OYJ
DE	GESELLSCHAFT BURGERLICHEN RECHTS	GBR	PL	SPOLKA AKCYJNA	SA
DE	OFFENE HANDELSGESELLSCHAFT	OHG	PL	SPOLKA PRAWA CYWILNEGO	SC
DE	GMBHCOKG	GMBH & CO KG	PL	SPOLKA KOMANDYTOWA	SK
DE	GESELLSCHAFT	GMBH	PL	SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA	SPZOO
FR	SOCIETE ANONYME SIMPLIFIEE	SAS	PL	SP Z OO	SPZOO
FR	SOCIETE ANONYME	SA	PL	SPZ OO	SPZOO
FR	SOC ANONYME	SA	PL	SP ZOO	SPZOO
FR	STE ANONYME	SA	GR	ANONYMOS ETAIRIA	AE
FR	SOCIETE A RESPONSABILITE LIMITEE	SARL	GR	ETERRORRYTHMOS	EE
FR	SOCIETE A RESPONSIBILITE LIMITEE	SARL	GR	ETAIRIA PERIORISMENIS EVTHINIS	EPE
FR	SARL UNIPERSONNELLE	SARLU	GR	OMORRYTHMOS	OE
FR	SOCIETE PAR ACTIONS SIMPLIFIEES	SAS	GR	SOCIETE ANONYME	SA
FR	SAS UNIPERSONNELLE	SASU	CZ	AKCIOVA SPOLECNOST	AS
FR	ENTREPRISE UNIPERSONNELLE A RESPONSABILITE LIMITEE	EURL	CZ	KOMANDITNI SPOLECNOST	KS
FR	ET COMPAGNIE	ETCIE	CZ	SPOLECNOST S RUCENIM OMEZENYM	SRO
FR	COMPAGNIE	CIE	CZ	VEREJNA OBCHODNI SPOLECNOST	VOS
FR	SOCIETE CIVILE IMMOBILIERE	SCI	BG	AKTIONIERNO DRUSHESTWO	AD
FR	GROUPEMENT D'INTERET ECONOMIQUE	GIE	BG	KOMANDITNO DRUSHESTWO	KD
FR	SOCIETE CIVILE	SC	BG	KOMANDITNO DRUSHESTWO S AKZII	KDA
			BG	DRUSHESTWO S ORGRANITSCHENA OTGOWORNOST	OCD

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, PT-Portugal.

Table A2: Identification of Non-Corporate Institutions

Country	String	Country	String
All	UK SEC FOR	DE	Fraunhofer-Gesellschaft
All	US ADMIN	FR	UNIV
All	US DEPT	FR	FONDATION
All	US SEC	FR	CENT NAT
GB	UNIV	FR	HOPITAL
GB	RES COUNCIL	FR	RECHE
GB	HOSPITAL	FR	INST
GB	NHS TRUST	FR	INST MERIEUX
GB	BONE MARROW TRUST	FR	FOND CENT NAT DE TRANSFUSION
GB	HEALTH SERVICE TRUST	FR	INST NAT DE LA SANTE&DE LA RECH
GB	BRITISH BROADCASTING CORPORATION	FR	DEUTFRANZOESISCHES FORSCHUNGSINST
GB	United Kingdom Atomic Energy Authority	FR	ISL INST FRANCOALLEMAND DE RECH
GB	NATIONAL RESEARCH DEVELOPMENT CORPORATION	FR	ANVAR Agence Nationale de Valorisation
ES	UNIV	BE	UNIV
ES	CONSEJO	DK	UNIV
ES	INVESTIGACION	NO	UNIV
IT	UNIV	NL	UNIV
IT	CONSIGLIO NAZIONALE	NL	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST
IT	ISTSUP	FI	UNIV
SE	UNIV	PO	UNIV
SE	FORSKNINGSINSTITUT	GR	UNIV
SE	STIFTELSE	CZ	UNIV
DE	UNIV	BG	UNIV
DE	EINGETRAGENER VEREIN	PT	UNIV

Table A3: Match Codes and Applicant Codes

Match Type	Description	Applicant Type	
0	No match	0	Corporate
1.1	Unique standard match	1.1	Automatically identified institution
1.2	Unique stem match	1.2	Automatically identified individual
1.3	Unique previous name match	2.1	Manually identified institution
2.1.0	***Multiple standard match, unresolved***	2.2	Manually identified individual
2.1.1	Multiple standard match, resolved by original name		
2.1.2	Multiple standard match, record change		
2.1.3	Multiple standard match, resolved by zip code		
2.1.4	Multiple standard match, allocated to Belenzon ultimate owner		
2.1.5	Multiple standard match, allocated to BVD ultimate owner		
2.2.0	***Multiple stem match, unresolved***		
2.2.1	Multiple stem match, resolved by original name		
2.2.2	Multiple stem match, record change		
2.2.3	Multiple stem match, resolved by zip code		
2.2.4	Multiple stem match, allocated to Belenzon ultimate owner		
2.2.5	Multiple stem match, allocated to BVD ultimate owner		
2.3.0	***Multiple previous name match, unresolved***		
2.3.1	Multiple previous name match, resolved by original name		
2.3.2	Multiple previous name match, record change		
2.3.3	Multiple previous name match, resolved by zip code		
2.3.4	Multiple previous name match, allocated to Belenzon ultimate owner		
2.3.5	Multiple previous name match, allocated to BVD ultimate owner		
3.1	Manual match, definite		
3.2	Manual match, probable		
3.3	Manual match to ultimate owner		
3.4	***Manual multiple matches, unresolved***		
3.5	***Manual match failed***		
3.6	Multiple match, manually resolved		

Notes: Match types that appear in italics are considered as failed and are not used in the final output.

Table A4: Output

Entity Name	Variable	Variable Description
Patent BVD Match	**Bvdidnumber**	Amadeus BVD no.
	appln_nr	'Real' Patent Application no.
	Country	Applicant country.
	applicant_name	Original applicant name from EPO.
	Year	Year patent application filed at EPO.
	match_type	Coded description of how match achieved, see table X.
	Uo	Amadeus ultimate owner
	Buo	Belenzon ultimate owner
	Muo	Manually assigned ultimate owner
Auxiliary Match File – Patents	**applicant_name**	Original PATSTAT applicant's name
	applicant_address	PATSTAT Applicant's address
	no_of_patents	Number of patents held by this applicant
	last_pat_year	Most recent year in which this applicant filed a patent application
	standard_name	Standardised applicant's name
	stem_name	Standardised applicant's name stripped of corporate extensions
	amadeus_name	Amadeus firm's name, null if not matched
	Bvdidnumber	Amadeus firm's BVD number, null if not matched
	Zipcode	Amadeus firm's zipcode, null if not matched
	Address	Amadeus firm's address, null if not matched
	Activeinactive	Amadeus firm has filed account in last four years, null if not matched
	Uo	Amadeus ultimate owner BVD number
	Dropped	Equals 1 if Amadeus firm has been dropped from Amadeus, null if not matched
	previous_name1/2/3/4	For UK firms - previous names from FAME
	standard_previous_name1/2/3/4	Standardised previous names

	Buo	Belenzon ultimate owner BVD number
	amadeus_file_no	Number of Amadeus file that this firm name came from
	match_type	Code describing how match was acheived. 0 if not matched
	Applicant_type	Identifies institutions and individuals. 0 if corporate
	manual_matcher	Researcher who assigned manual match.
	Comments	Description of manual match
	change_match	Set to 1 if manual match overwrites automatic match
	manual_uo	Manually assigned ultimate owner
	multiple_this_one	Multiple match resolved by address, record change, indicates correct match
Auxiliary Match File – Firms	amadeus_name	Amadeus firm's name
	standard_name	Standardised Amadeus name
	Uo	Amadeus ultimate owner BVD number
	Buo	Belenzon ultimate owner BVD number
	Stem_name	Standardised Amadeus name stripped of corporate extensions

CHAPTER 2 | PRODUCT MARKET REFORMS, LABOUR MARKET INSTITUTIONS AND UNEMPLOYMENT

Rachel Griffith, Rupert Harrison and Gareth Macartney

Abstract[24]

We analyze the impact of product market competition on unemployment, and how this depends on labour market institutions. Theoretically, both firms with market power and unions with bargaining power are constrained in their behaviour by the elasticity of demand in the product market. We use differential changes in regulations across OECD countries over the 1980s and 1990s to identify the effects of competition. We find that increased competition reduces unemployment, more so in countries with labour market institutions that increase worker bargaining power. We also find that competition increases real wages, but less so when bargaining power is high.

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[24] This chapter is identical to the version published in the Economic Journal. See Griffith, R., Harrison, R. and Macartney, G. (2007). ‘Product Market Reforms, Labour Market Institutions and Unemployment’, *The Economic Journal*, vol. 117, no. 519, pp. C142-C166.

1. INTRODUCTION

High rates of unemployment remain a key policy concern in many European countries. Following the OECD Jobs Study (1994) a large literature has investigated the role of unions, taxes, and other labour market institutions in explaining cross-country variation in unemployment rates.[25] Theory suggests that competition in the *product* market is also an important determinant of employment – in imperfectly competitive markets firms restrict output and thus employment. A number of recent theoretical papers have emphasized the role of product market competition, as well as potentially important interactions between competition and labour market institutions.[26] A recognition of the role of competition also lies behind many of the current attempts to reform product markets in Europe, including those laid out in the Lisbon Agenda and the Services Directive.

In this paper we investigate the impact of increased product market competition on employment using data across OECD countries over the 1980s and 1990s. Our contribution to the literature is twofold. First, we use time-varying policy reforms as a source of exogenous variation in product market conditions, enabling us to provide stronger evidence that competition increases employment than exists so far. We show that this effect has been quantitatively important in explaining movements in unemployment in OECD countries over the past twenty years.

Secondly, we provide evidence that the size of these effects varies with labour market institutions. Theory suggests that the positive impact of competition on employment is greater where workers' bargaining power is high. The reason for this is that unions which care about employment as well as wages are constrained from demanding high wages by the level of competition in the product market. Therefore an increase in competition in an economy with both monopolistic firms and unions will lead to greater reductions in prices and greater increases in output than in an economy without unions. We also investigate the parallel predictions of theory for the impact of product market competition on real wages (using real labour costs as a proxy measure). In contrast to the case with employment, under some conditions the positive impact of competition on real wages may be smaller when workers have more bargaining power, since the negative impact of competition on the general price level may be partially offset by a reduction in the level of rents

[25] See, amongst others, Elmeskov, Martin and Scarpetta (1998), Nickell and Layard (1999), Blanchard and Wolfers (2000), Belot and van Ours (2001). In a recent contribution to this literature, Nickell et al. (2005) find that changes in these factors can explain about 55% of the rise in European unemployment from the 1960s to the first half of the 1990s. Blanchard (2005) argues that a complex interaction between institutions and other shocks provides an important part of the explanation.

[26] See for example Blanchard and Giavazzi (2003), Spector (2004) and Ebell and Haefke (2004).

captured by workers. Finally, we also test whether these effects of competition on employment and labour costs depend on the degree of bargaining coordination.

We use the substantial market liberalisations that have occurred across countries over the past two decades to provide exogenous variation in competitive conditions. These include reforms that reduce barriers to entry, tariff rates, regulatory barriers to trade and reduce public involvement in production. We find strong evidence that reforms such as these decrease the average level of profits in the economy, which in turn increases employment and real wages. The positive effect on employment is found to be greater, and the positive effect on real wages lower, in economies with greater worker bargaining power (those with higher collective bargaining coverage and/or higher union membership).

Our work is related to three key literatures. First, as discussed above, there is a substantial empirical literature investigating the labour market determinants of unemployment. In general this work finds that labour market institutions, taxes and benefits have important effects on the level of employment, although the nature and size of the effects vary somewhat across studies.

Secondly, there is a body of theoretical work suggesting that increasing product market competition increases employment and real wages.[27] Several recent contributions to this literature emphasise that the employment increase is greater when workers bargain collectively, even when the workers' choice of bargaining regime is endogenised as in Ebell and Haefke (2004).

Thirdly, there is a recent and smaller empirical literature on the impact of product market regulations on employment and wages.[28] Most similar to this paper, Nicoletti and Scarpetta (2005) estimate the impact of product market reforms on employment rates across OECD countries. Consistent with the discussion above, they find that restrictive product market regulations have reduced employment rates in some OECD countries, particularly those where labour market institutions provide strong bargaining power to insiders. Our approach differs from Nicoletti and Scarpetta (2005) in a number of important ways: we use indicators of product market reforms that affect both traded and non-traded sectors of the economy, rather than a selection of seven regulated network industries as in their case; we allow the impact of product market reforms to vary across different types of reform, rather than imposing strong a priori restrictions by calculating a single

[27] The basic framework of several recent papers draws on elements of Dixit and Stiglitz (1977) and Blanchard and Kiyotaki (1987), combining monopolistic competition in the goods market and bargaining over employment and wages in the labour market. Blanchard and Giavazzi (2003) is a recent model without capital. Spector (2004) introduces capital and finds that real wages may actually decrease following an increase in competition.

[28] Studies at the micro level include Bertrand and Kramarz (2002) and Kugler and Pica (2003). At the country level, Pissarides (2001) finds a negative correlation between a measure of business start-up costs and employment rates across a sample of OECD countries.

index of regulation;[29] we investigate the parallel predictions of theory for real wages as well as employment; and, drawing on the underlying theoretical motivation, we explicitly model the impact of product market reforms on competition, as proxied by the average level of profits in the economy. Without this last step the channel for the impact of product market regulations on employment and wages is not clear.

In summary, there is strong empirical evidence that labour market institutions matter in determining labour market outcomes, there are strong theoretical reasons to believe that product market regulations are also important, but there is little empirical evidence to support this. In addition, some theory suggests that the impact of product market competition on labour market outcomes varies with labour market institutions. There is, however, even less empirical evidence to support this latter prediction.

The structure of the paper is as follows. Section 2 sets out a theoretical framework. In section 3 we explain our empirical methodology and discuss the data. Section 4 presents the results, and a final section concludes.

2. THEORETICAL FRAMEWORK

The main contribution of the paper is empirical, however, it is useful to briefly explain the theoretical framework we use. It is based on a standard closed economy model with monopolistic competition in the goods market and bargaining over wages in the labour market. Models of this type have been widely used in the literature, and form the basis of several recent papers investigating the impact of product market reforms, including Blanchard and Giavazzi (2003) and Spector (2004) amongst others.[30] The exact predictions for the impact of product market reforms on employment depend on a number of factors, including the precise nature of the bargaining process. However, the main theoretical intuition that we investigate empirically is best explained as the result of double marginalisation by firms and unions.

Consider a closed economy with N sectors, each consisting of one firm and one consumer-worker, and each represented by one union. Firms use labour to produce a single good, and the goods are imperfect substitutes. Worker-consumers have constant elasticity of substitution preferences and an increasing aversion to work.[31] Firms monopolise their sectors and unions monopolise firms, as they

[29] Previous work has suggested that this is an important consideration. See Griffith and Harrison (2004).

[30] Our exposition is based closely on the simple model in Chapter 15 of Carlin and Soskice (2006), consisting of elements from the classic models of Dixit and Stiglitz (1977) and Blanchard and Kiyotaki (1987). Very similar results arise in the model of Jackman, Layard and Nickell (1991).

[31] The increasing marginal disutility of work is necessary for a unique equilibrium in the presence of constant returns to scale production. It captures the idea that workers have a higher reservation wage in times of high employment, due for example to increased personal wealth, household income or more opportunities for employment.

control all of the labour in their sector. The expression for equilibrium employment under this double monopoly case takes the following form:

$$\log E^{\text{DoubleMonopoly}} = A\log\left[B\left(\frac{1}{1+\mu}\right)^{2}\right], \tag{1}$$

where E is equilibrium employment, the constant A contains the employment elasticity of the disutility of employment, B is a scaling parameter, and μ is the mark-up of price over marginal cost. Compare this, first, to a situation with imperfect product market competition but no unions (equation 2), and, second, to the perfectly competitive outcome with no unions (equation 3):

$$\log E^{\text{FirmMonopoly}} = A\log\left[B\left(\frac{1}{1+\mu}\right)\right], \tag{2}$$

$$\log E^{\text{Competitive}} = A\log B. \tag{3}$$

As we would expect $\log E^{\text{Competive}} > \log E^{\text{FirmMonopoly}} > \log E^{\text{DoubleMonopoly}}$. A single margin, due to imperfect competition in the product market, reduces equilibrium employment below the perfectly competitive level, while a second margin, due to the presence of monopoly unions, reduces it still further. From expressions (1) and (2) it is also clear that an increase in product market competition that reduces the mark-up will increase employment, and will increase it more in the presence of a monopoly union. This is the key idea that we investigate empirically.

In our empirical application we use country level measures of collective bargaining coverage and trade union membership to capture variation in the nature of wage and employment setting.[32] One way to interpret this is that countries with a higher proportion of workers covered by collective bargaining agreements, or belonging to unions, correspond more closely to the double-monopoly case, while countries with lower levels of bargaining coverage or union membership correspond more closely to the single firm-monopoly case. For example, we could think of countries with higher levels of bargaining coverage or union membership as having a higher proportion of sectors characterized by the double-monopoly case.

An alternative interpretation is that collective bargaining coverage or union membership are summary measures of workers' bargaining power in a setting where there is bargaining between firms and unions. Union power may be constrained by a number of factors such as regulations on the right to strike, the extent of control over the workforce or the presence of other unions. At one extreme of workers' bargaining power lies the monopoly union and at the other extreme is the single firm monopoly, with a range of bargaining power in between. The intuition described above

[32] We also consider the role of bargaining coordination – see below for a discussion of this.

then has an equivalent as follows: an increase in product market competition that decreases the mark-up will increase employment more when workers' bargaining power is higher.[33]

From this discussion we take the following empirical predictions to the data.

PREDICTION 1 *Increased product market competition reduces unemployment.*

PREDICTION 2 *The reduction in unemployment is larger when workers' bargaining power is higher.*

1.1. Wages

Our main interest in this paper is in the impact of product market competition on employment. However, it is also interesting to consider the parallel implications for wages. These are less clear than the impact on employment. In the simple model described above, the effect of increased competition on real wages is independent of union bargaining power. The equilibrium real wage, w^e, is entirely determined by product market conditions and it increases with competition as follows:

$$w^e = \frac{1}{1+\mu}. \tag{4}$$

The result that the real wage is independent of union bargaining power is a direct consequence of the assumption that firms can set prices and employment conditional on the bargained wage. In this *right to manage* framework firms set prices as a mark-up over the bargained wage and the impact on the general price level offsets any increase in the bargained wage. If, on the other hand, we assume *efficient bargaining*, where firms and unions bargain over employment and the real wage simultaneously, then the real wage becomes a positive function of union bargaining power – workers are able to capture a proportion of the available rents, and it is increasing in their bargaining power. In this case an increase in competition that reduces the available rents will increase the real wage by a smaller amount when workers have higher levels of bargaining power. Competition hurts individuals as workers but, through its effect on the price level, benefits them as consumers.

As discussed in Blanchard and Giavazzi (2003), while efficient bargaining may not be a complete description of the actual bargaining processes, it does capture the possibility that, when there are rents, stronger workers may be able to obtain a higher wage without suffering a decrease in

[33] This result also comes directly out of recent theoretical models of product and labour market regulation. For example, in the case where firms have the right to manage it is implicit in equation (14) of Blanchard and Giavazzi (2003) and equation (6) of Spector (2004). The equivalent results for the case of efficient bargaining are equation (6) in Blanchard and Giavazzi (2003) and equation (7) in Spector (2004). In a dynamic framework, Ebell and Haefke (2004) find that the positive effect of competition on employment is greater when workers bargain collectively than when they bargain individually, even when the choice of bargaining institution is endogenous.

employment, at least in the short run. To the extent that this is the case, we would expect to see that the positive impact of competition on wages is smaller when workers have more bargaining power.

Another consideration with regard to wages concerns the role of fixed capital. In the presence of fixed capital in the production function, workers and firms will bargain over the resulting quasi-rents. Spector (2004) shows that in this case the overall impact of product market competition on wages may be negative, as the reduction in workers' rents and quasi-rents more than offsets the reduction in the price level.

From this discussion we take the following empirical predictions to the data.

PREDICTION 3 *Increased product market competition increases the real wage.*

PREDICTION 4 *The increase in the real wage may be smaller when workers' bargaining power is higher, to the extent that bargaining deviates from the right to manage framework.*

1.2. A Note on Coordination

Finally, an important characteristic of union bargaining is the degree to which unions coordinate their activities. Calmfors and Driffill (1988) argue that there should be a U-shaped relationship between employment and the degree of coordination.[34] The reason for this is that unions have an incentive to coordinate in sectors that are close substitutes in order to decrease the elasticity of demand for their (combined) product. However, as the combined union becomes larger the effect of its wage demands on aggregate prices increases. Its members suffer from this and worker-consumers therefore moderate their demands, and employment increases. In this way an intermediate level of coordination, at the industry level for example, results in the lowest employment, since union bargaining power is high, but worker-consumers have little incentive to take into account the impact of their wage demands on the aggregate price level.

To the extent that true economy-wide coordination that leads to more moderate wage demands does exist, we should expect to see that the interaction between product market competition and measures of union density or bargaining coverage is less strong in coordinated countries. However, to the extent that the main effect of coordination is to increase workers' bargaining power we should expect to find that the impact of competition on employment is larger (and the impact on wages smaller) in more coordinated economies. We look for these effects in the results section.

[34] The original paper made predictions concerning bargaining centralisation, although subsequent work focussed on coordination as a fuller measure of at which level bargaining occurs. Robust empirical evidence for the hump-shaped relationship has proved elusive and the debate on the impact of centralisation/coordination continues. See Flanagan (1999) for a discussion.

2. EMPIRICAL IMPLEMENTATION AND DATA

The discussion above suggests that competition will affect the unemployment rate, and will do so differently in economies with different labour market institutions. We are therefore interested in empirically exploring the following relationship:

$$UR_{it} = \alpha_1 \mu_{it} + \alpha_2 \mu_{it} * BP_i + LMR'_{it}\alpha_3 + X'_{it}\alpha_4 + f_i + t_t + \varepsilon^U_{it} \,, \qquad (5)$$

where i indexes countries and t years, UR is the unemployment rate, μ is a measure of the average level of profits firms earn, BP_i captures labour market regulations that indicate the bargaining power of workers in the economy (at the start of the sample period – see below), LMR_{it} is a vector of other labour market regulations and institutions, and X_{it} contains a set of cyclical and other controls, including a measure of the deviation of output from trend growth, the real exchange rate, the change in the inflation rate and the public sector employment rate to control for any potential impact of public sector employment in crowding out private sector employment. We check that our results are robust to this set of control variables, and also check that the results are robust to using employment rather than unemployment as the dependent variable. Country fixed effects are captured by country dummies, f_i, and common macro shocks by year dummies, t_t.

We capture the extent of product market competition by the average level of firm profitability in the economy, μ. Therefore, a key issue in estimating (5) and (6) is the potential for endogeneity of μ, as well as measurement error. For example, a positive demand shock might increase both output and firm profitability. We pay careful attention to instrumenting μ using policy reforms to product markets. We show that the reforms affect average profitability in the economy in a way that accords with theory, and we confirm the power of our instruments. Our approach assumes that such reforms affect labour market outcomes only through their impact on competition and not directly. We test the statistical validity of these exclusion restrictions. It is crucial that we have indicators of product market regulations and reforms that vary differentially over time across countries or industries as this allows us to identify the key parameters of interest separately from other cross country differences.

In examining how the effect of competition depends on labour market institutions we focus on labour market characteristics that affect workers' bargaining power. We capture this using indicators of collective bargaining coverage and trade union membership, which in themselves may be endogenous: for example, an adverse shock on employment or wages may trigger an increase in union membership. Therefore, we use initial values of coverage and union density to capture variation in workers' bargaining power across countries. The implicit assumption is that bargaining power does not change significantly over time, and the data suggests that this is not an unreasonable assumption, particularly for bargaining coverage.

We also explore two auxiliary results. First we estimate an exactly equivalent specification for real labour costs as follows:

$$w_{it} = \beta_1 \mu_{it} + \beta_2 \mu_{it} * BP_i + LMR'_{it} \beta_3 + X'_{it} \beta_4 + f_i + t_t + \varepsilon^W_{it}, \quad (6)$$

where w is the log of real labour costs per hour and all other notation is as above. As with unemployment, we pay careful attention to instrumenting μ using policy reforms to product markets. Secondly, we investigate whether the relationships described in equations (5) and (6) depend on the degree of bargaining coordination. The exact specification we use to do this is described later on.

In order to investigate these issues empirically we need data on (i) unemployment, (ii) wages or labour costs, (iii) the extent of product market competition and indicators of exogenous product market reforms, (iv) labour market regulations, and (v) other country characteristics. We discuss each of these in turn below. For precise definitions, means and standard deviations see tables A1-A.3 in the Appendix. We provide further description of the key variables over time for each country in a web appendix available at www.ifs.org.uk/ghm07.

2.1. Unemployment

We use the OECD's standardised unemployment rate, which is the number of unemployed persons as a percentage of the civilian labour force. This is important because, in general, decreases in the unemployment rate are associated with increases in participation (e.g. see Blanchard, 2005). Our story is one of bargaining power and the medium run equilibrium in the labour market, so we are keen to isolate these from participation effects. However, we also check that our results are robust to using employment rather than unemployment as a dependent variable.

2.2. Wages and Labour Costs

Unfortunately, comparable wage data is not available for all countries in our sample at the total economy level. We therefore use total economy labour costs, which includes payroll taxes. We control for the tax wedge for our main results. We show that our results are robust to the use of a real wage index for manufacturing, which is available for a sub-sample of country-year observations.

2.3. Product Market Competition and Reforms

We capture changes in the extent of competition using a measure of the average level of firm profitability (excluding the public sector, agriculture and the real estate sector).[35][36] In a simple model of bargaining, such as that set out in Section 2, this corresponds closely to the equilibrium mark-up over costs. We calculate the average level of profits as value added over costs:

$$\mu_{it} = \frac{ValueAdded_{it}}{LabourCosts_{it} + CapitalCosts_{it}}, \tag{7}$$

where all variables are in nominal prices.[37] We use the US long term interest rate to proxy the time variation in the cost of capital, under the assumption that this proxies the world interest rate.[38] The average level of profitability in our sample is 1.31. The measure is pro-cyclical and varies both within and between countries (see Table A.2 and Figure A.1, www.ifs.org.uk/ghm07).[39] We therefore include a measure of deviation from trend output growth and the change in the rate of inflation to control for country specific business cycles, as well as the real exchange rate to control for trade shocks. In addition, country dummies control for any differences in measurement that are constant over time.

A drawback of our measure is that it contains the implicit assumption of constant returns to scale. This measure of profitability is biased downwards (upwards) in the presence of increasing (decreasing) returns to scale. However, any bias that might arise due to different levels of increasing returns to scale across countries should be captured by the country fixed effects in our econometric analysis, since the industrial mix does not change very quickly over time. Similarly, any trends that are common across countries will be captured by year effects.

Key to our identification strategy is the use of time-varying indicators of product market reforms for each country. We use information on four types of reform - the implementation of the EU Single Market Programme (SMP), changes in tariff and non-tariff barriers and the burden of government bureaucracy.

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[35] We can think of this as an estimate of the mark-up or price cost margin (similar to a Lerner Index) if average costs are close to marginal costs. This is shown by Boone (2000) to be theoretically preferable to most other commonly used measures of competition, especially those based on market concentration or the number of firms, and it most closely corresponds to the parameter specified in theoretical models.

[36] Real Estate suffers from inflated values due to rising property prices. In Portugal we cannot make these exclusions due to lack of data so we use the total economy. We can remove the real estate sector in Austria, Denmark, Finland, France, the Netherlands, Norway and the US.

[37] This can be shown to be equivalent to that proposed by Roeger (1995). See also Klette (1999) for a discussion.

[38] We repeat the analysis using time-varying country specific interest rates (see the robustness section for discussion).

[39] Overall, our measures are similar to other examples in the literature, for example those calculated for manufacturing industries by Martins, Scarpetta and Pilat (1996).

The SMP was concerned with eradicating cross-country differences in product and service standards, administrative and regulatory barriers, VAT and capital controls which inhibited the free flow of goods, services and factors of production between EU countries. Of the 14 countries in our sample, seven were involved in the programme (Belgium, Denmark, France, UK, Italy, the Netherlands and Portugal) and seven were not (Australia, Austria, Canada, Finland, Norway, Sweden, US). We also exploit the fact that, among participants, the SMP both had a differential impact across countries and was implemented at different rates.

To capture variation in the impact across countries we use a survey carried out before the programme was implemented. Cecchini et al. (1988) surveyed 11,000 firms in different industries asking respondents to rate the current level of various barriers to trade. Based on this survey Buiges et al. (1990) identified 40 out of 120 industrial sectors that were deemed to be most sensitive to the programme. They consulted individual country experts to confirm their findings and to add or remove sectors from the list according to country-specific circumstances. Table 1 lists the percentage of industry employment in each country that Buiges et al. (1990) identified as sensitive to the programme, showing that the Netherlands was deemed the least sensitive and Portugal the most sensitive. As well as different ex ante sensitivity to the SMP, different countries passed the necessary reforms into law at different rates. The European Commission recorded this from 1997 onwards in its Internal Market Scoreboard and we modify our SMP variable accordingly using differences across countries in the average rate of implementation.[40]

Table 1: Measures of Product Market Reform and Bargaining Power

Country	Industry Sensitive to Single Market Program (%)	Collective Bargaining Coverage in 1986 (%)	Union Density in 1986 (%)
Australia	0	85	45.1
Austria	0	99	50.6
Belgium	50.2	90	51.5
Canada	0	39	33
Denmark	49.4	74	77.4
Finland	0	95	88.2
France	50.8	90	12.5
UK	50.0	64	44.8
Italy	52.2	85	40.4
Netherlands	44.9	80	27.3
Norway	0	70	57.1
Portugal	68.1	70	51.4
Sweden	0	86	82.5
US	0	21	17

Notes: The size of industries that were deemed sensitive to the SMP is measured as % of employment.

[40] The scoreboard is available at http://europa.eu.int/comm/internal_market/score/index_en.htm.

We combine these sources of variation to construct a variable that indicates the percentage of industry liberalized over time, the exact form of which can be seen in www.ifs.org.uk/ghm07.

We use three other indicators of product market reform. The first is an indicator of the administrative burden on business due to government bureaucracy, which may constitute a barrier to firm entry. The second is a measure of the extent of hidden import barriers and costs to importing equipment, which may inhibit competition. Both of these indicators are based on survey responses from 10,000 business leaders carried out in the Executive Opinion Survey and published in the World Economic Forum's Global Competitiveness Report. These indicators are available for the 1990s. The third is an index of average tariff rates, reported in Fraser Institute (2002) based on data from a number of sources, including the World Bank, the OECD, UNCTAD and GATT.

In the results reported below we pay careful attention to showing that these reforms provide powerful instruments for the degree of profitability (in that they enter significantly in the first stage regression) and that they are valid instruments (in that statistical tests suggest that they can be excluded from the second stage).

2.4. Labour Market Regulations

To measure worker bargaining power we use two variables - the proportion of workers who are paid wages determined by firm/union bargaining, whether or not they belong to a union (referred to as bargaining coverage), and the proportion of workers who are actual members of a union (referred to as union density). We find bargaining coverage a more convincing and accurate measure of bargaining power, and use it in the first instance, and consider union density for robustness.[41] The start of sample values of bargaining coverage and union density are listed for each country in Table 1. As controls we use a set of labour market variables that have been found to be important in the unemployment literature. They are: an index of employment protection legislation; the benefit replacement ratio; the tax wedge between the production wage and the consumption wage; and a measure of the degree of coordination of bargaining in the economy.[42]

3. RESULTS

We now turn to an empirical investigation of the predictions set out in section 1. We start by considering the first stage, or reduced form, regression of average profitability on the indicators of product market reforms, before moving on to the main results examining the effects of changes in

[41] The classic example is that of France, which has the lowest union density in our sample (12.5%), but a very high level of bargaining coverage (90%).

[42] See Nickell at al (2005) for a discussion of these variables and their impact on unemployment outcomes.

competition on unemployment. We follow with an investigation of the further predictions on wages and the effect of bargaining coordination.

3.1. The Effect of Product Market Reforms on Average Profitability

The first stage regression of average profitability on indicators of product market reforms and all other controls takes the following form:

$$\mu_{it} = PMR_{it}'\gamma_1 + LMR_{it}'\gamma_2 + X_{it}^{'}\gamma_3 + f_i + t_t + \varepsilon_{it}^{\mu}, \quad (8)$$

where i indexes country, t year, PMR_{it} represents a vector of time and country varying indicators of product market regulation, LMR_{it} represents a vector of time and country varying indicators of labour market regulation (which are also included in the employment and wage regressions later on), and X includes the output gap, changes in inflation, the real exchange rate, and the share of employment accounted for by the public sector, as discussed in Section 3.

Table 2: The Impact of Product Market Reforms on Competition

Dependent variable:	Profitability (μ_{it})			Profitability (μ_{it}) * Bargaining Coverage in 1986
	(1)	(2)	(3)	(4)
Single Market Programme	-0.00066	-0.00048	-0.00060	-0.01364
	[0.00026]	[0.00031]	[0.00032]	[0.02778]
Average Tariff Rate		-0.02813	-0.02064	-10.50267
		[0.01601]	[0.05146]	[4.10911]
Government Bureaucracy		-0.00387	-0.09118	-5.23088
		[0.00822]	[0.06655]	[5.29911]
Non-Tariff Barriers		0.02075	0.01997	1.28659
		[0.01435]	[0.01516]	[1.31458]
Average Tariff Rate * Bargaining Coverage 1986			-0.00017	0.09813
			[0.00058]	[0.04713]
Government Bureaucracy * Bargaining Coverage 1986			0.00103	0.05005
			[0.00079]	[0.06331]
Tax Wedge * Bargaining Coverage 1986			0.00010	0.00935
			[0.00007]	[0.00651]
Labour market controls: Tax wedge, employment protection, benefits, coordination	Yes	Yes	Yes	Yes
Other controls: output gap, change in inflation, real exchange rate, public sector employment rate, country and year dummies	Yes	Yes	Yes	Yes

Notes: The regressions include 206 observations on 14 countries over the period 1986-2000. Robust standard errors are in parentheses. See Table 3 for tests of the joint significance and partial R^2 of the four product market reform variables.

All of the product market variables are increasing with liberalisation, so a negative coefficient suggests that reforms which liberalise product markets are associated with lower average profitability. Column (1) in Table 2 shows the first stage using the SMP variable alone. We can see that it is statistically significant and negative, meaning that entering the SMP was associated with a reduction in average profitability, which we interpret as a positive impact on competition. The magnitude of the SMP effect is such that, if the SMP affected 50% of industry, as it did in the case of the UK for example, then we estimate that economy-wide average profitability decreases by 3 percentage points (0.00066*50).[43] In Column (2) we include three other product market reforms, and the four variables together are jointly significant at the 1% level. This is the first stage regression used to identify the linear competition effect in column (3) of Table 3.

We estimate equations (4) and (5) both for the linear case (restricting α_2 and β_2 to be zero) and including the interaction terms with bargaining power (α_2 and β_2 non-zero). Therefore we need reduced forms for both the linear variable and the interaction. In column (3) we interact the product market reforms with bargaining coverage. In the long run, when the number of firms in the economy is endogenous, Blanchard and Giavazzi (2003) show that the equilibrium level of rents in the economy depends on both entry costs and workers' bargaining power, which justifies including these interactions in the first stage.[44] We show at the bottom of column (5) of Table 3 that the excluded instruments have strong explanatory power, in the sense that they are jointly significant at the 1% level and have a partial R-squared of about 9%. In column (4) we show the reduced form for the interaction term, which has similar properties.

3.2. Unemployment

We now turn to the estimation of the determinants of unemployment, as expressed in equation (4). In Table 3 we start in column (1) by looking at the relationship between labour market regulations and the unemployment rate. The results are consistent with those in Nickell et al. (2005), and several other studies, in that taxes and the benefit replacement rate have a significantly positive effect on unemployment and coordination has a negative effect, whereas employment protection legislation has no significant effect on its own.[45] The output gap has a significant negative coefficient as expected, the change in the inflation rate is not significant, and the real exchange rate has a significant negative coefficient, indicating that a more appreciated exchange rate is associated with a lower equilibrium level of unemployment. The coefficient on the public sector employment

[43] That is, for example, from 0.13 to 0.10, or from 13% to 10%.

[44] See equation (8) of Blanchard and Giavazzi (2003). We also tried including the SMP interacted with bargaining coverage but found that the data rejected this specification in the sense that the Hansen test in the second stage rejected the over-identifying restrictions.

[45] Nickell et al. (2005) find that interactions between different labour market institutions can be important in explaining unemployment. We do not investigate this possibility as our main focus is on the impact of product market competition.

rate is significantly higher than minus one, suggesting that unemployment decreases less than one-for-one with an increase in public sector employment. In the robustness section we show that the results are robust to dropping some of these controls.

Table 3: The Impact of Competition on the Unemployment Rate

Dependent variable: Unemployment Rate	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	OLS	IV	OLS	IV	OLS	IV
Competition Variables							
Profitability		6.857	17.102	-17.858	-0.272	-13.361	1.700
		[2.402]	[8.612]	[5.705]	[12.975]	[3.855]	[7.538]
Profitability * Bargaining Coverage in 1986				0.300	0.375		
				[0.062]	[0.134]		
Profitability * Union Density in 1986						0.297	0.157
						[0.049]	[0.078]
Labour Market Controls							
Tax Wedge	0.109	0.118	0.131	0.079	0.099	0.039	0.083
	[0.047]	[0.047]	[0.048]	[0.047]	[0.060]	[0.044]	[0.046]
Employment Protection Legislation	-0.271	-0.225	-0.157	-0.035	0.172	0.193	0.033
	[0.289]	[0.279]	[0.268]	[0.266]	[0.328]	[0.270]	[0.281]
Benefits Replacement Ratio	10.72	9.591	7.905	6.943	2.360	8.810	8.268
	[2.984]	[3.055]	[3.149]	[2.948]	[3.844]	[2.455]	[2.525]
Coordination Index	-1.328	-1.446	-1.622	-1.172	-1.513	-0.885	-1.245
	[0.364]	[0.367]	[0.384]	[0.391]	[0.485]	[0.327]	[0.363]
Other Controls							
Output Gap	-0.515	-0.563	-0.635	-0.566	-0.733	-0.545	-0.592
	[0.044]	[0.047]	[0.075]	[0.046]	[0.074]	[0.046]	[0.058]
Change in Inflation	-1.454	0.246	2.786	-0.231	5.549	-1.259	0.822
	[5.830]	[5.740]	[6.325]	[5.555]	[8.278]	[4.999]	[5.007]
Real Exchange Rate	-0.070	-0.057	-0.037	-0.062	-0.018	-0.063	-0.049
	[0.012]	[0.013]	[0.022]	[0.012]	[0.023]	[0.012]	[0.016]
Public Sector Employment Rate	-0.546	-0.537	-0.523	-0.396	-0.329	-0.491	-0.505
	[0.122]	[-.0109]	[0.093]	[0.107]	[0.119]	[0.102]	[0.091]
Constant	4.783	-4.778	-19.061	35.951	-29.396	35.451	-8.651
	[2.829]	[4.248]	[12.780]	[8.513]	[12.346]	[7.079]	[8.436]
1st Stage P-value: linear			0.0053		0.0016		0.0001
interaction			-		0.0003		0.0000
1st Stage Partial R^2: linear			0.06		0.09		0.15
interaction			-		0.11		0.26
P-value for Hansen test of over-identifying restrictions			0.20		0.27		0.08

Notes: The regressions include 206 observations on 14 countries over the period 1986-2000. Robust standard errors are in parentheses. All specifications include country and year dummies. The 1st Stage P-value is for a test of the joint significance of the excluded product market reforms, and the 1st Stage Partial R^2 is for the excluded product market reforms. In column (3) they are based on the estimates in column (2) of Table 2, in column (5) they are based on the estimates in columns (3) and (4) of Table 2, and in column (7) they are based on the equivalent specification to columns (3) and (4) in Table 2 but with bargaining coverage replaced by union density.

In column (2) we include the linear effect of average profitability on unemployment. The significant positive coefficient suggests that increasing competition (a decrease in profitability) decreases the unemployment rate. Controlling for the endogeneity of competition by using our IV estimator in column (3) indicates that the OLS estimates are negatively biased, as the coefficient becomes more positive when we instrument. This is as expected: for example unobserved shocks that increase profitability are likely to decrease unemployment. Instrumenting will also help to reduce any attenuation bias that may be present due to classical measurement error in profitability. At the bottom of column (3) we present diagnostics showing the strength and validity of the excluded instruments. The p-value and partial R2 of the excluded instruments suggest that they have power, and the Hansen test suggests that we cannot reject the over-identifying restrictions that the policy reform variables can be excluded from this regression.

In columns (4) and (5) we look at how the impact of increased competition varies with collective bargaining coverage, measured at the beginning of the sample period to mitigate potential problems of endogeneity.[46,47] In columns (6) and (7) we consider the equivalent interaction with union density. The results provide evidence of interaction effects with both bargaining coverage and union density, and in both cases they are as theory predicts: an increase in competition decreases the unemployment rate more so in the presence of strong worker bargaining power. In the case of bargaining coverage the interaction effect becomes slightly larger once we instrument, whereas with union density the interaction becomes smaller, but the linear effect larger. We have no strong *a priori* reason to believe that the direction of the bias in the interaction term should be positive or negative. However, the mean effect in both cases increases, which is consistent with the hypothesis that any bias in profitability dampens the estimated effect of competition. At the bottom of columns (5) and (7) the p-values for the test of significance of the excluded instruments and the partial R2 suggest that the instruments have power. In column (5) we cannot reject the validity of the overidentifying exclusion restrictions, while in column (7) we cannot reject at the 5% level, but can at the 10% level.

[46] The results are robust to letting bargaining coverage vary over time in the interaction, and including it as a control. In this case the coefficients (standard errors) on profitability and the interaction between profitability and bargaining coverage are –4.533 (9.856) and 0.376 (0.104) respectively. The result also holds with time-varying union density.

[47] We exclude Germany as we expect the effects of re-unification to swamp any impact of product market reforms around that time period. When we do include data for Germany, controlling for re-unification with a dummy variable, the coefficients (standard errors) on profitability and the interaction between profitability and bargaining coverage are –4.293 (12.371) and 0.404 (0.129).

3.3. Economic Significance

What are the economic magnitudes of these effects? The magnitude of the results in column (3) suggest that the 3 percentage point drop in profitability predicted for the UK's entry into the SMP would, all else equal, result in a decrease in the unemployment rate of 0.51 of a percentage point (17.10*-0.03). To assess the magnitude of the interaction in column (5) we can compare the effect of a 3 percentage point drop in profitability on economies that have a bargaining coverage one standard deviation either side of the mean (which is 75%). An economy with an initial coverage of 53%, somewhere between that of Canada (39%) and the UK (64%), will experience a decrease in the unemployment rate of 0.60 percentage points (-0.03*(-0.27+0.38*53)), whereas an economy with an initial coverage of 97%, similar to that of Austria (99%), will experience a decrease of 1.10 percentage points (-0.03*(-0.27+0.38*97)), a difference of half a percentage point. The coefficient when we use union density is smaller and the comparable difference in the unemployment effect between a low density economy and a high density economy is 0.21 percentage points, again corresponding to one standard deviation either side of the cross-country mean. The smaller interaction effect with union density is consistent with our view that, perhaps, it does not measure bargaining power as well as coverage.

Table 4 further quantifies the economic significance of our estimates by comparing the actual changes in unemployment for each country between 1988 and 1998 (the years between which we have a balanced panel of countries) to the predicted changes from product market reforms based on our estimates. We first examine the predicted impact of the SMP for participant countries, and then the predicted impact of changes in all the product market reform variables. In all cases we control for common year effects, country-specific business cycles and macroeconomic shocks, so changes are relative to the cross-country average. We also control for the share of employment in the public sector. The predicted changes use estimates from column (5) of Table 3.

The table shows that the predicted effects of product market reforms in reducing unemployment are substantial. For some of the countries the SMP variable accounts for a large part of the impact, but the other product market variables also explain a significant amount of variation. For example, our estimates suggest that the SMP was associated with a 1.1 percentage point reduction in the unemployment rate in Portugal, while all the product market reforms that we measure were together associated with a 2.6 percentage point reduction. This compares with an actual reduction in the unemployment rate relative to the cross-country average trend of 1.1 percentage points. Thus, factors other than product market reforms appear to have been responsible for an increase in the unemployment rate relative to the cross-country average trend of 1.5 percentage points. Overall the predicted changes due to all the product market reforms are positively correlated with the actual changes across countries, with a correlation coefficient of 0.35.

Table 4: Predicted Effects of Product Market Reforms, 1988 to 1998

Country	(1) ΔUnemployment	(2) Explained by SMP	(3) Explained by all product market reforms	(4) Explained by labour market reforms
Australia	0.2	0.0	-0.2	0.3
Austria	2.9	0.0	-0.2	0.9
Belgium	-1.6	-1.0	-0.4	0.1
Canada	-3.5	0.0	0.2	0.3
Denmark	-0.4	-0.8	-2.2	0.1
Finland	4.8	0.0	1.6	0.4
France	1.3	-1.0	-1.3	0.7
UK	-5.9	-0.7	-1.3	-0.3
Italy	0.2	-1.0	-1.1	-0.9
The Netherlands	-1.2	-0.8	-2.9	-0.7
Norway	2.7	0.0	-1.4	0.8
Portugal	-1.1	-1.1	-2.6	-0.5
Sweden	2.5	0.0	-0.3	-0.4
US	-1.0	0.0	-0.2	-0.2

Notes: All columns are calculated using de-trended values, controlling for the business cycle, the real exchange rate, changes in the inflation rate, and the public sector employment rate. Predictions are based on coefficient estimates reported in column (5) of Table 3.

The predicted effect of the SMP, on the seven countries that participated, was an average decrease in the unemployment rate of 0.9 of a percentage point. This is sizeable when compared to the average change in the unemployment rate for the same seven countries between 1988 and 1998, which was, with controls, a decrease of 1.2 percentage points (0.5 percentage points without any controls).

These effects vary substantially with different levels of bargaining coverage. Still using the values from column (2) of Table 4 we can compare the impact of the SMP on unemployment in the UK to that in Belgium (the estimated impact of the SMP on average profitability for these two countries is the same – a reduction of 3.0 percentage points). We estimate that the SMP reduced unemployment in the UK (where bargaining coverage was 64%) by 0.7 percentage points, whereas in Belgium (where bargaining coverage was 90%) the SMP reduced unemployment by 1.0 percentage points.

There is, however, a lot of variation in unemployment that we do not explain. Continuing to consider the seven SMP countries, the predicted effect of all product market reforms (including the SMP) is an average decrease of 1.7 percentage points and the predicted net effect of labour market reforms is a decrease of 0.2 percentage points. This leaves an increase in unemployment of 0.7 percentage points unexplained. It is possible that our results underestimate the overall impact of reforms to labour market institutions. In particular, Nickell et al. (2005) find that interactions between labour institutions are significant determinants of unemployment; for the sake of parsimony, we have not explored this here.

3.4. Labour Costs

Table 5 presents the results for the wage regression as written in equation (6). As mentioned previously, comparable total economy wage data is unavailable for these countries. Therefore, we present results for real labour costs per hour for the total economy. This includes payroll taxes and other non-wage labour costs.

We start in column (1) by ensuring that the simple labour cost regression is consistent with existing literature. The coefficients on the labour market institutional variables are consistent with Nunziata (2005) in that the tax wedge and benefit replacement ratio increase labour costs, and the coordination index decreases labour costs (although it is only significant at 10% here). However, whereas in our sample the employment protection index has a negative coefficient, Nunziata (2005) finds a positive coefficient. The theoretical predictions for the impact of protection legislation are ambiguous (see Blanchard (2005) for a discussion) and the results may differ due to the difference in samples: Nunziata (2005) uses 20 OECD countries over the period 1960-1994.

Table 5: The Impact of Competition on Labour Costs

Dependent variable: Log Real Labour Costs per Hour	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5) IV
Competition Variables					
Profitability		-21.025	-114.644	-124.116	-176.422
		[10.336]	[56.607]	[28.126]	[61.486]
Profitability * Bargaining Coverage in 1986				1.245	1.803
				[0.313]	[0.569]
Labour Market Controls					
Tax Wedge	0.593	0.568	0.459	0.368	0.272
	[0.163]	[0.160]	[0.197]	[0.161]	[0.167]
Employment Protection Legislation	-2.028	-2.189	-2.909	-0.945	-0.436
	[1.072]	[1.037]	[1.359]	[1.040]	[1.055]
Benefit Replacement Ratio	24.208	27.759	43.571	14.893	10.175
	[8.814]	[8.750]	[13.152]	[8.350]	[9.550]
Coordination Index	-3.225	-2.847	-1.163	-2.035	-1.561
	[1.894]	[1.850]	[1.946]	[1.899]	[1.824]
Other Controls					
Output Gap	0.109	0.255	0.908	0.261	0.307
	[0.150]	[0.146]	[0.421]	[0.148]	[0.314]
Change in Inflation	14.657	9.349	-14.284	9.295	7.714
	[32.625]	[29.936]	[32.477]	[31.640]	[32.918]
Real Exchange Rate	0.218	0.177	-0.004	0.160	0.141
	[0.051]	[0.054]	[0.128]	[0.052]	[0.087]
Constant	136.958	166.248	296.666	416.462	217.467
	[11.394]	[17.923]	[80.801]	[33.395]	[56.449]
1st Stage p-value: linear			0.0227		0.0329
interaction					0.0013
1st Stage Partial R^2: linear			0.05		0.06
interaction					0.10
P-value for Hansen test of over-identifying restrictions			0.61		0.08

Notes: The regressions include 206 observations on 14 countries over the period 1986-2000. Robust standard errors appear in parentheses. Country and year dummies are included throughout. The 1st Stage P-value is for a test of the joint significance of the excluded product market reforms, and the 1st Stage Partial R^2 is for the excluded product market reforms. In column (3) they are based on estimates similar to those shown in column (2) of Table 2 but with non-tariff barriers excluded, in column (5) they are based on equivalent specifications to columns (3) and (4) in Table 2 but with non-tariff barriers excluded. The dependent variable has been multiplied by 100, to aid presentation.

In column (2) we include profitability in an OLS regression on real labour costs for the total economy and find that increased rents reduce real labour costs, as expected. In column (3) we use an instrumental variables estimator to control for the potential endogeneity of profitability. At the bottom of the table we show that the instruments are both powerful and valid for profitability in this specification. The significant negative coefficient on profitability suggests that competition has a positive effect on wages. The difference between the OLS and IV estimates suggests that the OLS coefficient is biased upwards, as would be expected if there was a positive correlation between profitability and wages due to unobserved shocks or other factors.

To assess the economic significance of these results consider as before the impact of joining the SMP on a country such as the UK where 50% of industry was expected to be affected. The coefficient on profitability in column (3) of Table 5 implies that the predicted impact of the SMP in the UK was an increase in real labour costs of about 3.4% (-0.03*-114.64). Thus, if we interpret labour costs as a proxy for wages, workers were on average made better off by this amount.

In column (4) we include the interaction with bargaining coverage in an OLS regression, and in column (5) we use our IV estimator. Recall from Section 1 that, to the extent that bargaining deviates from right-to-manage, we expect the positive impact of competition on real wages to be smaller in countries where workers have high levels of bargaining power. The results in column (5) are consistent with this prediction. Consider the same 3 percentage point reduction in average profitability as a result of the SMP. The size of the effect in column (5) is such that a low bargaining coverage country (53% as before) would experience an increase of about 2.4% in real labour costs (-0.03*(-176.42+1.80*53)), whereas a high coverage country (97% as before) would experience an increase of only 0.1% (-0.03*(-176.42+1.80*97)). Theory suggests that workers should be better off on average in all countries and our results are largely consistent with this: with bargaining coverage up to 98% the interaction effect does not outweigh the linear effect. In our sample only Austria has coverage higher than this.

As a robustness check we estimated an equivalent specification to that in column (5) but for an index of real wages in manufacturing.[48] The results are similar, with coefficients (standard errors) on the linear profitability variable and the interaction of –79.082 (23.550) and 0.546 (0.306) respectively. Combining these with the coefficient on the SMP variable from the first stage (from which we estimate that the SMP reduced average profitability in UK manufacturing by about 9 percentage points) implies that a low bargaining coverage country would experience a 4.5% increase in real manufacturing wages as a result of joining the SMP, while a high coverage country would experience an increase of only 2.3%. In this case the average effect on real wages is positive even with 100% coverage.

3.5. Bargaining Coordination

As described in Section 1.2 we may expect that our results will vary with the degree of bargaining coordination in the economy. If the degree of coordination is high enough that it successfully

[48] We lose observations for Portugal and some years for other countries, leaving 176 observations.

moderates wage demands we expect our interaction result to be less strong in highly coordinated countries, however to the extent that it increases workers' bargaining power then we expect the impact of competition on employment to be larger (and the impact on wages to be smaller) in more coordinated economies. To investigate this we split the countries in our sample into three groups according to the average value of their coordination index. The highly coordinated countries are Austria, Denmark, Finland, The Netherlands and Norway; the intermediate ones are Belgium, France, Italy, Portugal and Sweden; and the low coordination countries are Australia, Canada, the UK and the US.[49] We then estimate a modified version of equation (5) for the unemployment rate as follows:

$$\begin{aligned} UR_{it} &= \alpha_1 \mu_{it} + \alpha_2 \mu_{it} * BP_i + \alpha_3 \mu_{it} * INT_i + \alpha_4 \mu_{it} * HIGH_i \\ &+ \alpha_5 \mu_{it} * INT_i * BP_i + \alpha_6 \mu_{it} * HIGH_i * BP_i \\ &+ LMR'_{it} \alpha_7 + X'_{it} \alpha_8 + f_i + t_t + \varepsilon^U_{it} , \end{aligned} \tag{9}$$

where *INT* and *HIGH* are dummies for intermediate and high coordination respectively and all other notation is as before. If the effect of competition on unemployment is higher in intermediate or highly coordinated countries we expect α_3 or α_4 to be positive. This would be the case if the main effect of coordination was to increase workers' bargaining power by lowering the elasticity of demand for their (combined) product. If coordination also leads to moderated wage demands through the internalization of negative externalities then we expect the interaction between competition and bargaining coverage to be weaker in more highly coordinated countries, in which case we expect α_5 or α_6 to be negative.

The first column of Table 6 shows the results of estimating equation (9). While the estimated coefficients on the three way interactions between profitability, bargaining coverage and the coordination dummies are indeed negative, they are both insignificant, and the same is true for the two-way interactions between profitability and the coordination dummies. In the second column we set α_5 and α_6 to zero and include only the interactions between the coordination dummies and profitability. As well as a significant positive coefficient on our main interaction of interest - between profitability and bargaining coverage - we also find significant positive coefficients on both of these additional interactions. Thus the largest effect of increased competition on unemployment appears to be in countries where bargaining coverage is high and coordination is also intermediate or high.

[49] The results are robust to changing the categorisation so that only Finland, The Netherlands and Norway are considered as highly coordinated.

Table 6: Coordinated Bargaining

Dependent variable:	Unemployment Rate		Log of Real Labour Costs Per Hour, Total Economy	
	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
Profitability	-22.012	-20.089	-125.531	-121.213
	[6.489]	[5.595]	[33.393]	[27.465]
Profitability * Bargaining Coverage in 1986	0.230	0.201	0.989	0.923
	[0.083]	[0.079]	[0.547]	[0.430]
Profitability * Intermediate Coordination Dummy	36.675	12.735	-9.509	0.809
	[37.627]	[4.465]	[421.416]	[23.411]
Profitability * High Coordination Dummy	17.706	10.918	53.641	35.417
	[17.954]	[4.169]	[58.575]	[20.570]
Profitability * Intermediate Coordination Dummy * Bargaining Coverage in 1986	-0.289	-	0.104	-
	[0.442]		[4.883]	
Profitability * High Coordination Dummy * Bargaining Coverage in 1986	-0.088	-	-0.233	-
	[0.204]		[0.782]	
Labour market controls: Tax wedge, employment protection, benefits, coordination	Yes	Yes	Yes	Yes
Cyclical controls: output gap, change in inflation, real exchange rate, public sector employment rate	Yes	Yes	Yes	Yes
Observations	206	206	206	206

Notes: Robust standard errors appear in parentheses. All specifications include country and year dummies. The highly coordinated countries are Austria, Denmark, Finland, Netherlands and Norway; the intermediates are Belgium, France, Italy, Portugal and Sweden; and the low coordination countries are Australia, Canada, UK and US. The results are robust to changing the categorisation so that only Finland, The Netherlands and Norway are considered as highly coordinated.

In columns (3) and (4) we repeat the same exercise for the log of real labour costs per hour in the total economy and the results are qualitatively similar.[50] As before, our previous results are robust and the three-way interactions between profitability, the coordination dummies and bargaining coverage are insignificant in column (3). In column (4) the interaction between profitability and the high coordination dummy is positive and significant, but only at the 10% level. Overall these results are consistent with the idea that the main effect of the degree of bargaining coordination actually observed in our sample is to increase workers' bargaining power, rather than to internalize the negative externalities of excessive wage demands. At the very least they suggest that the impact of competition on unemployment is larger in more coordinated countries.

3.6. Robustness

Finally, we turn to a number of potential robustness concerns, not previously discussed. We consider whether our main results are robust to the following: a different measure of the cost of

[50] The results using the manufacturing real wage index are also similar.

capital used in calculating profitability; changing the control variables used; and using employment instead of unemployment as the dependent variable. These are discussed in turn.

In our main results we use the US long term interest rate to proxy variation over time in the cost of capital for all countries. This assumes that capital markets are fully open throughout the sample period, which we find to be the most plausible assumption. If capital markets were liberalized by some countries during the sample period in a way that was correlated with reforms to product markets this could potentially affect our results. To check the robustness of our results we re-ran all results making the extreme assumption that capital markets are fully closed, and hence used domestic interest rates to proxy for changes in the cost of capital. Our main results are robust to this change.[51]

We also check that our main results are robust to the set of control variables included. For example, if we drop the change in the inflation rate, the real exchange rate and the public sector employment rate from the specification in column (5) of Table 3 the main results are not significantly affected. For example, the coefficients (standard errors) on profitability and the interaction between profitability and bargaining coverage are 5.826 (10.980) and 0.345 (0.137) respectively.

Another potential measurement concern is with our use of the unemployment rate as the dependent variable. To investigate this we instead use the log of employment as the dependent variable, and include the size of the labour force as a control, as well as the log of public sector employment. The key difference between this and the unemployment regressions is that we no longer restrict the coefficient on the labour force to equal one. The key coefficients on profitability, and the interaction between profitability and bargaining coverage, are robust to this change of specification. For example the equivalent coefficients (standard errors) on profitability and its interaction with bargaining coverage to those in column (5) of Table 3 are –0.042 (0.150) and –0.004 (0.001). The magnitude of these estimated effects are very similar to those using the unemployment rate. For example, consider again the impact of joining the SMP for a country with high bargaining coverage (97% as before). Using the coefficients above this is associated with a 1.30% increase in employment (-0.03*100*(-0.042-0.004*97)), which is comparable with a predicted reduction in the unemployment rate of 1.10 percentage points calculated from column (5) of Table 3. The equivalent changes for a low bargaining coverage country (53% as before) are a 0.76% increase in

[51] For example, for the instrumented unemployment regression (Table 3 column 3) the coefficient (standard error) on profitability, for the 185 observations for which the domestic interest rate is available, is 12.792 (4.777). In Table 3 column (5) the coefficients (standard errors) on profitability and the profitability*bargaining coverage terms are -1.093 (9.100) and 0.168 (0.103) respectively. For the instrumented wage regression, using real labour costs per hour for the total economy (Table 5 column 5) the equivalent coefficients (standard errors) are -115.751 (28.206) and 1.556 (0.310).

employment (-0.03*100*(-0.042-0.004*53)) and a 0.60 percentage point reduction in the unemployment rate predicted by column (5) of Table 3.

4. CONCLUSION

High rates of unemployment remain a key policy concern across many European countries. Attention has focused on labour market institutions as the main determinant of unemployment, but recent work suggests that they cannot fully explain the variation across countries and over time. We have shown here that conditions in the product market are important determinants of unemployment, as well as interactions between product markets and labour markets. Having said that, there remains significant variation in unemployment to be explained.

Empirically we have shown that the significant product market de-regulation experienced in the 1990s by some OECD countries was associated with an increase in competition as measured by average firm profitability. Such exogenous increases in competition are further associated with increases in aggregate employment and the real wage. We estimate that in countries with higher levels of collective bargaining coverage and/or union density the increase in employment is more pronounced, and the increase in real wages (labour costs) less so. Although some of the key reforms that we have used specifically targeted manufacturing, we find that even manufacturing workers with very high bargaining coverage were, in real wage terms, better off on average as a result of the product market reforms.

Our results have interesting implications for policy. First, widespread product market reforms will tend to benefit workers and the economy as a whole through increased employment and higher real wages. Second, the presence of strong unions is not a reason to shy away from product market reform – if anything there is more incentive to reform as the employment benefits may be larger. However, given that we find a positive average impact of product market reforms on wages, our results raise the question of why workers and unions are often hostile to reforming product markets. One answer suggested by our results is that existing workers with more bargaining power have less to gain on average from product market reforms. However, our results have focused solely on average effects across the whole economy. We have not considered the possibility of piecemeal reforms that only affect the sector in which an individual works and not the goods they consume. In this case workers with bargaining power may lose out overall. This suggests that widespread reforms are less likely to be resisted by workers than reforms that only affect a small number of sectors.

DATA APPENDIX

Our data consist of an unbalanced panel on 14 countries over the period 1986-2000. Table A.1 shows the structure of the panel. Spain and Greece are excluded from the analysis due to a lack of data availability, and Germany is excluded due to re-unification, which is likely to have swamped any effects from product market reform. The second panel of Table A.1 shows the mean and standard deviation of our measure of profitability. It is important to note that the inclusion of country dummies in all specifications controls for average differences across countries in the level of measured profitability due to differences in measurement or other differences that are constant over time. Thus the main results are identified from differential within-country changes over time.

Table A.1: Sample Composition and Average Profitability by Country

Country	Total economy Unemployment, Labour Costs	Manufacturing Wages	Mean of Average Profitability	Standard Deviation
Australia	1986-2000	1986-2000	1.2944	0.0596
Austria	1986-2000	1986-1999	1.2716	0.0505
Belgium	1986-2000	1986-1998	1.2995	0.0349
Canada	1986-2000	1986-2000	1.3972	0.0534
Denmark	1986-2000	1986-2000	1.4980	0.0456
Finland	1986-2000	1986-2000	1.2120	0.1011
France	1986-2000	1986-1997	1.2828	0.0259
UK	1986-2000	1986-2000	1.3679	0.0527
Italy	1986-2000	1986-2000	1.4889	0.0832
The Netherlands	1986-2000	1986-1999	1.2419	0.0560
Norway	1986-1999	1997-1999	1.2297	0.1283
Portugal	1988-1999	-	1.2222	0.0275
Sweden	1986-2000	1986-2000	1.2029	0.0664
US	1986-2000	1986-2000	1.3698	0.0376
Total	206	176	1.3127	0.1123

Table A.2: Descriptive Statistics and Variable Definitions – Profitability, Labour Market Outcomes and Control Variables

Variable	Description and source	Mean (s.d.)
Profitability (priv. sec.)	$\mu_{it} = \frac{ValueAdded_{it}}{LabourCosts_{it} + CostofCapital * Capitalstock_{it}}$	1.3127 (0.1123)
Profitability (manuf.)		1.2128 (0.0986)
Value added	Value added at basic prices plus taxes, less subsidies on production, excluding imports and VAT. At factor costs for Canada and producer's prices for USA; OECD STAN database.	669345 (1136497)
Labour costs	Wages and salaries plus supplements, such as contributions to social security, private pensions, health insurance, life insurance. OECD STAN database	390341 (671321)
Cost of capital	Yield on USA Government composite bond (10 Years), minus inflation rate, plus assumed depreciation of 7%. OECD Main Economic Indicators for bond yields and consumer price index.	0.1118 (0.0075)
Capital stock	Calculated using the perpetual inventory method. Depreciation rates are calibrated so that the stocks are similar to the OECD estimates when both are available. OECD STAN database.	1094195 (1431343)
Unemployment rate	Standardised unemployment rate for all countries except Austria, for which we use the "commonly used definition". OECD Main Economic Indicators.	7.3650 (2.7414)
Employment	All persons engaged in domestic production including the self-employed. Countries are advised to report the number of jobs, rather than headcounts, subject to availability. OECD STAN database.	18698 (33187)
Real labour costs per hour	Wages and salaries plus supplements, such as contributions to social security, private pensions, health insurance, life insurance per hour worked. Deflated by the CPI, expressed here in US dollars (2000 exchange rate). OECD STAN database.	13.4592 (3.4204)
Real wages (manufacturing)	Real wage index for manufacturing; ILO, Key International Labour Market statistics.	102.7 (6.6)
Output gap	Percentage deviation of output from trend; OECD Economic Outlook.	-0.3488 (2.4411)
Change in inflation	Change in growth of consumer price index for all goods, from previous year; OECD Main Economic Indicators.	-0.0020 (0.0140)
Real exchange rate	Ratio of home country's prices to a weighted average of competitor country's prices, relative to a base year (2000) and measured in US dollars. Therefore an increase is an appreciation of the home country's real exchange rate. OECD Main Economic Indicators.	106.2 (12.2)

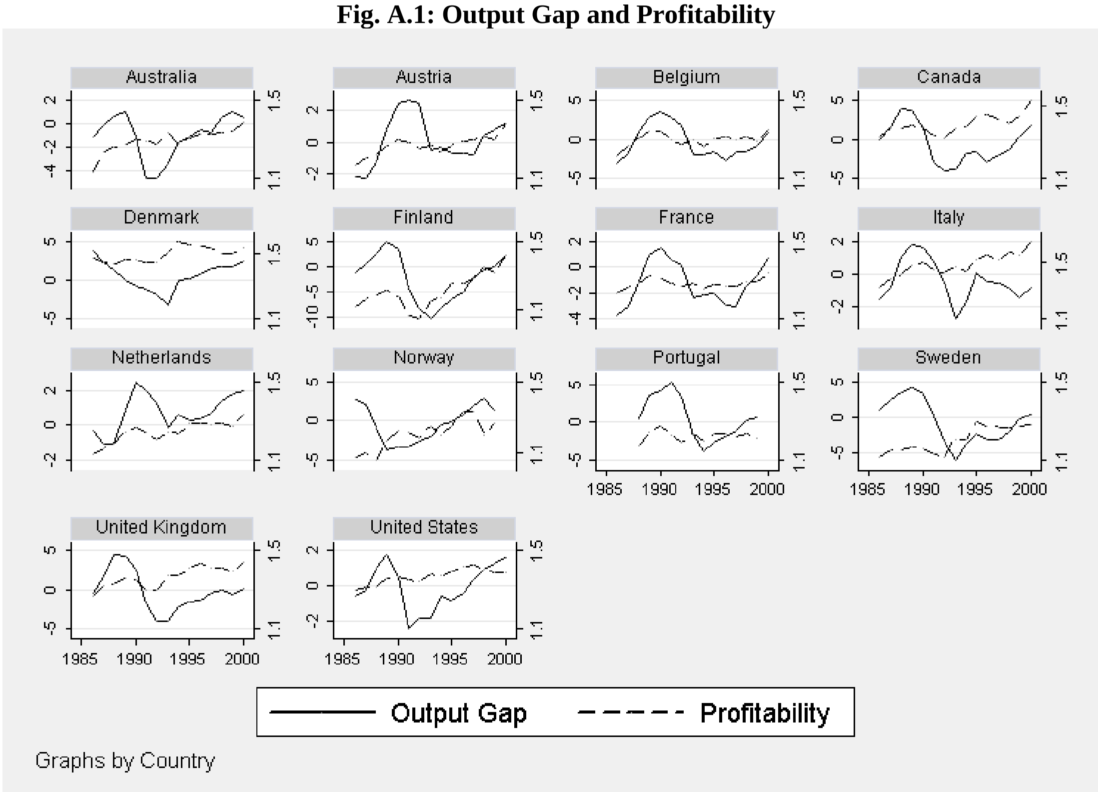
Table A.3: Descriptive Statistics and Variable Definitions - Product and Labour Market Regulations

Variable	Description and source	Mean (s.d.)
Single Market Programme	We use the percentage of employment (value added in the case of Belgium due to lack of data availability) in industry "liberalized" by the SMP. The variable from 1997 onwards is calculated as % of industry identified ex-ante to be sensitive to SMP times the EU's transposition index measuring % of reforms actually implemented. The variable is linearly extrapolated back to the programme start date, and is everywhere zero for those countries not in the programme	10.660 (18.450)
Average Tariff Rate	This is an index of the average tariff rate constructed by Fraser Institute from a number of sources, including the World Bank, the OECD, UNCTAD and GATT. It varies between 1 and 10, where 1 indicates very high tariffs and 10 indicates none at all.	8.670 (0.437)
Government Bureaucracy	This is and index constructed from responses to the question: "How much time does your firm's senior management spend dealing/negotiating with government officials?". This is available for the years 1995 and 2000. The World Economic Forum	7.418 (0.552)
Non-Tariff Barriers	This is based on survey questions on hidden import barriers and the cost of importing equipment to measure changes in the trade environment that are not captured in the SMP variable. Fraser Institute	8.326 (0.830)
Union density	Actual union members as percentage of employees. OECD Labour Force Statistics.	45.25 (25.16)
Union coverage	Percentage of employees covered by collective bargaining, whether they are union members or not. Nickell (2003), originally obtained from Wolfgang Ochel.	73.78 (23.20)
Employment protection legislation	An average of an indicator of legislation for regular contracts (covering procedural inconveniences, direct cost of dismissal, notice and trial period) and an indicator for legislation for temporary contracts (covering types of work admissible under temporary contracts and maximum cumulative duration allowed). Nicoletti et al (2000).	2.129 (1.193)
Benefits replacement ratio	Based on replacement ratio of the first year of unemployment. Nickell (2003), originally obtained from OECD Jobs Study 1994.	0.482 (0.181)
Tax wedge	Average of the tax wedge for one-earner family with two children and single persons without children. OECD, Taxing Wages, 2003.	36.20 (8.85)
Coordination index	The degree of coordination of bargaining: 1- firm level, 2- industry level, 3- economy level. We use coordination index 2 from Nickell(2003), originally obtained from Wolfgang Ochel.	1.926 (0.607)

FURTHER DATA APPENDIX

Figure A.1 shows the evolution of the output gap and profitability over time for each country. It is clear that our measure of profitability is pro-cyclical, and it is thus important to control for the cycle using the output gap.

Fig. A.1: Output Gap and Profitability



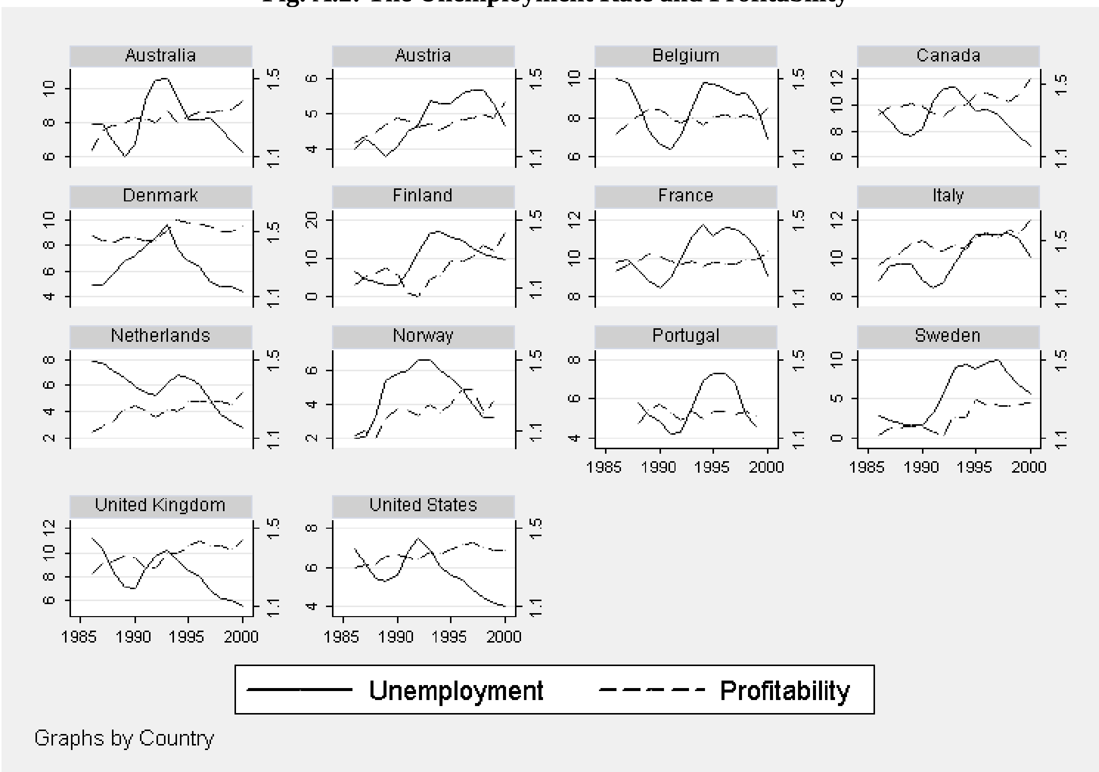
Notes: Data is from the OECD STAN database. The right hand side axis shows profitability, the left hand side shows the output gap. The output gap is defined by the OECD as percentage deviation of output from trend. Profitability is value-added over labour and capital costs.

At first the fact that average profitability trends upwards over time may seem to conflict with most preconceptions about changes to the degree of competition associated with product market reforms, globalisation and opening to trade. One explanation, discussed in Blanchard and Giavazzi (2003) and Boulhol (2004), is that upwards trending measured firm profits could be a short term response to reductions in the bargaining power of workers. The intuition is that declining bargaining power reduces the share of rents captured by workers in higher wages, and increases the share that is measured in firms' profits.[52] In the long term, the increase in profitability associated with declining workers' bargaining power would be expected to lead to entry and a reduction of rents to their previous level, but to the extent that these effects occur with lags it is possible for the rent transfer effect to dominate the entry effect during the transition period. We control for these types of changes by including time-varying measures of labour market institutions in all specifications. In addition, any trends that are common across countries will be captured by year effects.

[52] This is in a context of efficient bargaining. The intuition remains valid to the extent that bargaining deviates from the right-to-manage framework.

Figure A.2 shows that, without any control variables profitability and unemployment, although weakly positively correlated, often move in opposite directions, as expected.

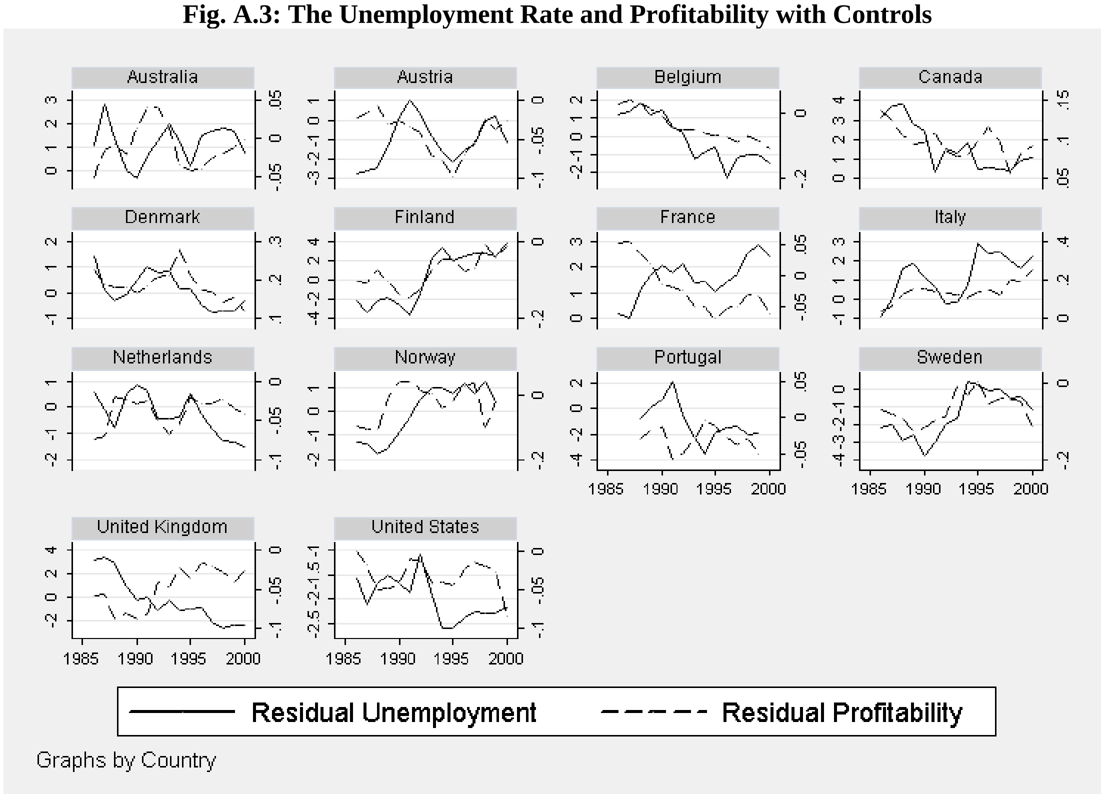
Fig. A.2: The Unemployment Rate and Profitability



Notes: Data is from the OECD STAN database. The right hand side axis shows profitability, the left hand side shows the unemployment rate.

Figure A.3 shows that, with the full set of labour market controls and time dummies (see paper), unemployment and profitability move together more closely.

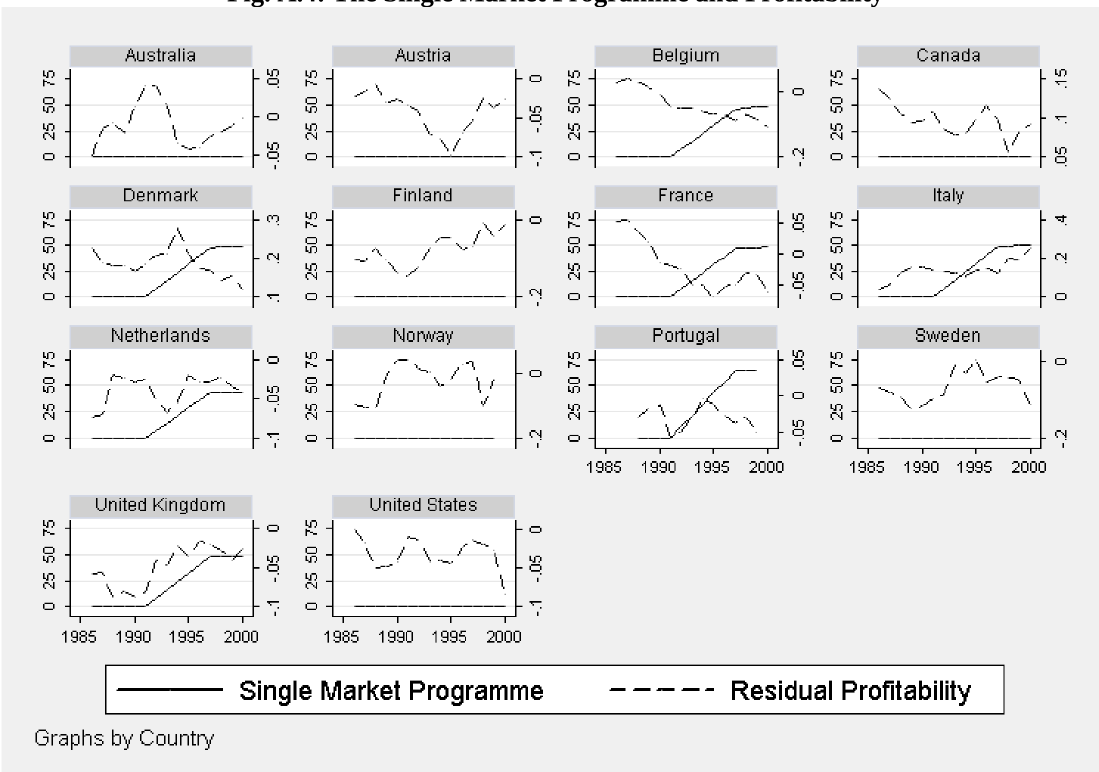
Fig. A.3: The Unemployment Rate and Profitability with Controls



Notes: Data is from the OECD STAN database. The right hand side axis shows profitability, the left hand side shows the unemployment rate. Both variables have controls for the business cycle, exchange rate shocks, a time trend and changes in labour market regulations.

Figure A.4 shows the Single Market Programme (SMP) variable and the profitability measure (with full controls for labour market institutions and year dummies).

Fig. A.4: The Single Market Programme and Profitability



Notes: Data is from the OECD STAN database. The right-hand side axis shows profitability, the left-hand side shows expected impact of the Single Market Programme. Profitability has controls for the business cycle, exchange rate shocks, a time trend and changes in labour market regulations.

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CHAPTER 3 | PRODUCT MARKET COMPETITION, FINANCIAL INSTITUTIONS AND INNOVATION

Gareth Macartney

Abstract

This paper finds evidence of complementarities between product market competition and financial institutions, as determinants of innovation. Recent research has found that product market competition increases innovation, particularly in sectors that are technologically advanced, i.e. have high initial innovation rates. Financial institutions that reduce monitoring costs faced by investors are theoretically associated with higher innovation rates. We find that increased competition has a bigger effect on innovation in the presence of such financial institutions. We use exogenous variation in competitive conditions across manufacturing industries and European countries that arose due to the adoption of the Single Market Programme. The positive effect of competition on innovation is found to be bigger in countries with more numerous credit institutions and lower deposit insurance. The results are robust to controlling for other institutions that may affect the competition-innovation relationship.

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1. INTRODUCTION

For some time economists have postulated both positive and negative effects of product market competition on innovation. Recent empirical studies have found considerable evidence that on average increased product market competition (PMC) leads to increased innovation (Nickell 1996, Blundell, Griffith and Van Reenen 1999). However, the effect seems to depend on initial conditions, in that PMC increases innovation more in initially technologically advanced sectors (Aghion, Bloom, Blundell, Griffith and Howitt 2005, Aghion, Blundell, Griffith, Howitt and Prantl 2006). The theory is that incumbent firms in technologically advanced sectors can escape their competitors through radical innovation, and increased competitive pressure will increase their incentive to do so. As noted in the conclusion to Aghion and Griffith (2005), understanding the interplay between PMC and institutions in labour and capital markets is one of many challenges in coming up with practical policy advice for innovative sectors. Indeed, there is evidence that labour market institutions have an effect (Aghion, Burgess, Redding and Zilibotti 2003). The current paper investigates how financial institutions affect the relationship between PMC and innovation, which to the author's knowledge has not been empirically investigated to date.

This paper uses product market reforms to identify the effect of increased PMC on innovation rates in manufacturing sectors and how this effect varies across countries with different financial institutions. We find evidence of complementarities between PMC and financial institutions as determinants of innovation, in that the effect of PMC on innovation is more positive in the presence of good financial institutions. The intuition is that good financial institutions reduce monitoring costs faced by investors and therefore promote investment in innovation. This increases the proportion of sectors that are technologically advanced and over which PMC increases innovation effort. The result is robust to controlling for labour and legal institutions that may be correlated with financial institutions.

There has been a long debate in economics as to whether the availability of external finance has a causal impact on economic outcomes such as investment, innovation and growth. There is now reasonable support from the finance and growth literature that it does (see Levine 2005 for a comprehensive survey). Country level empirical studies suggest that countries with a greater abundance of private credit (financial deepening) grow faster (see King and Levine 1993a and

Beck, Levine and Loayza 2000). Aghion, Howitt and Mayer-Foulkes (2005) find that countries with greater financial deepening converge to a common growth rate more quickly. At the industry level Rajan and Zingales (1998) find that sectors that are more dependent on external finance grow faster in countries with high financial deepening. However, it is not just an abundance of finance that matters, as Dehejia and Lleras-Muney (2003) note *"…whereas financial development can contribute to growth, the choice of institutional mechanism to induce financial development matters."* The Dehejia and Lleras-Muney paper shows that manufacturing growth rates in US states before World War II were positively associated with bank branching (the existence of small local bank branches rather than large centralized banks), but negatively associated with state deposit insurance schemes. Most importantly here, the literature distinguishes institutions that are associated with better monitoring with those that are not: small local banks easily gather information on investment projects, whereas deposit insurance schemes lesson the incentive for investors to ensure their money is being invested wisely. In support, Claessens and Laeven (2005) find that sectors grow faster with higher levels of competition in the banking sector. Galindo, Schiantarelli and Weiss (2005) find that financial liberalisation improves the allocation of capital, in that it is more targeted at firms where the estimated marginal productivity of capital is higher. Laeven (2003) estimates that firms are less financially constrained in the presence of liberal financial markets.

The finance literature emphasizes the monitoring role played by financial institutions in distinguishing between good and bad investment projects (Diamond 1984, King and Levine 1993b). The specialist nature of innovation suggests that informational problems are particularly pronounced and, indeed, the financing behaviour of innovative firms seems to support this (see Hall 2002 for a survey).[53]

The main idea in this paper comes from the combination of two literatures. The literature on competition and innovation suggests that initial conditions matter: competition has a more positive effect on innovation when initial steady state innovation rates are high. The finance

[53] Aghion et al. (2004b) find that when firms use external finance for innovation it is more often in the form of equity rather than debt, as equity instruments are more suitable for long term, risky projects with high information asymmetries. Bond, Harhoff and Van Reenen (1999) find that cash flow is a determinant of the R&D participation decision for firms in the United Kingdom (although not for firms in Germany), suggesting that external finance comes at a high premium for innovation. There is considerable evidence that even large firms are financially constrained by external finance costs in that their investment displays high cash flow sensitivity, see for example Fazzarri et al. (1998), Bond and Meghir (1994), although there is some debate as to whether cash flow sensitivity indicates financial constraints: see Kaplan and Zingales (1997) in opposition and Bond and Soderbom (2006) in support.

literature suggests that good financial institutions that reduce monitoring costs for investors increase steady state innovation rates. The idea explored in this paper is whether the impact of competition is stronger in the presence of financial institutions associated with lower monitoring costs, i.e. whether these two policies are complementary.

We use two indicators of financial institutions: the number of credit institutions[54] per capita and the ratio of deposit insurance to GDP. The theoretical and empirical literature suggests that these measures will be related to steady state innovation rates. A large number of credit institutions per capita may reduce monitoring costs for investors for at least two reasons. Firstly, small lenders have a comparative advantage in lending based on 'soft' information (Berger et al. 2005), which may be particularly important for investment in innovation which is by its nature investment in intangibles. Secondly, the presence of many small lenders enforces hard budget constraints which starves bad quality projects of capital, alleviating adverse selection problems as banks know they are less likely to lend to bad projects (Dewatripont and Maskin 1995).[55] There are agency costs in delegating monitoring to financial intermediaries (Diamond 1984) and investors must exert pressure on financial intermediaries to ensure good lending. One institution that reduces investors' incentives to exert this pressure is deposit insurance. This has been found to be associated with indiscriminate credit expansions, poor productivity growth and bank failures (Dehejia and Lleras-Muney 2003, Wheelock and Wilson 1995).

We can see statistically significant correlations between innovation in manufacturing and the number of credit institutions (see Figure 1) and deposit insurance (see Figure 2). These descriptive pictures suggest that numerous credit institutions are associated with high steady state innovation rates and deposit insurance schemes are associated with low steady state innovation rates. We explore the robustness of these results, and use the fact that these countries experienced large product market reforms in the 1990s as part of the Single Market Programme (differential across industries) to investigate whether the effect of PMC on innovation is more positive in economies with numerous credit institutions and less positive in economies with high deposit insurance.

[54] Deposit and savings banks.

[55] Carlin and Mayer (2003) provide empirical evidence that high tech sectors grow faster in countries with fractured banking systems.

Figure 1: Manufacturing Patents and the No. of Credit Institutions (all firms)[56]

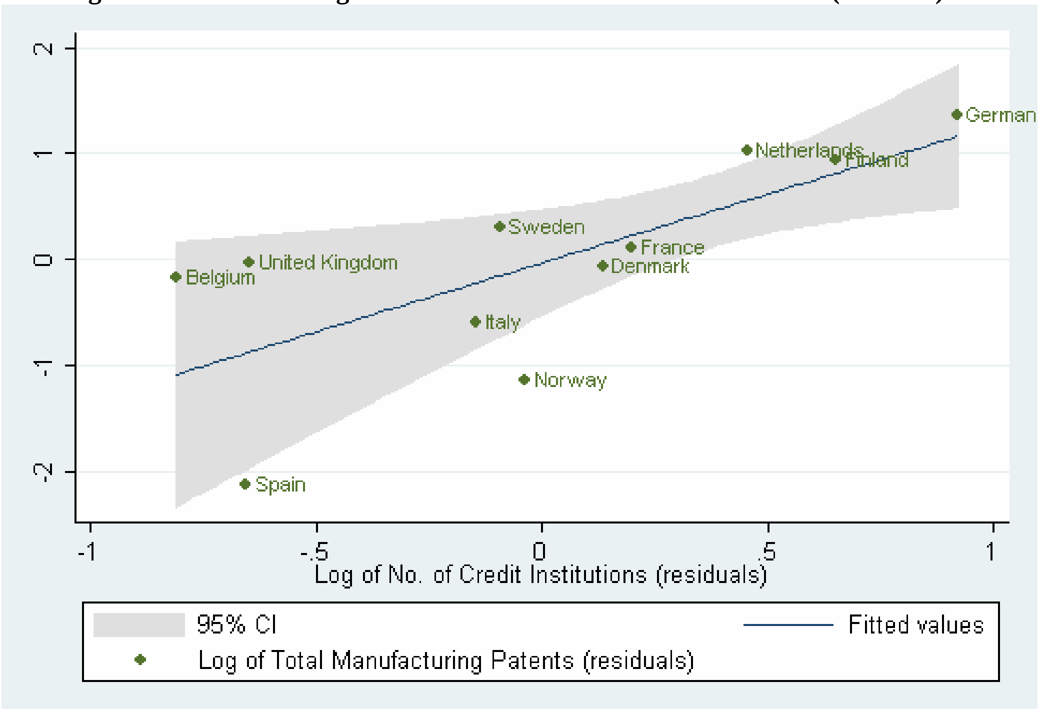
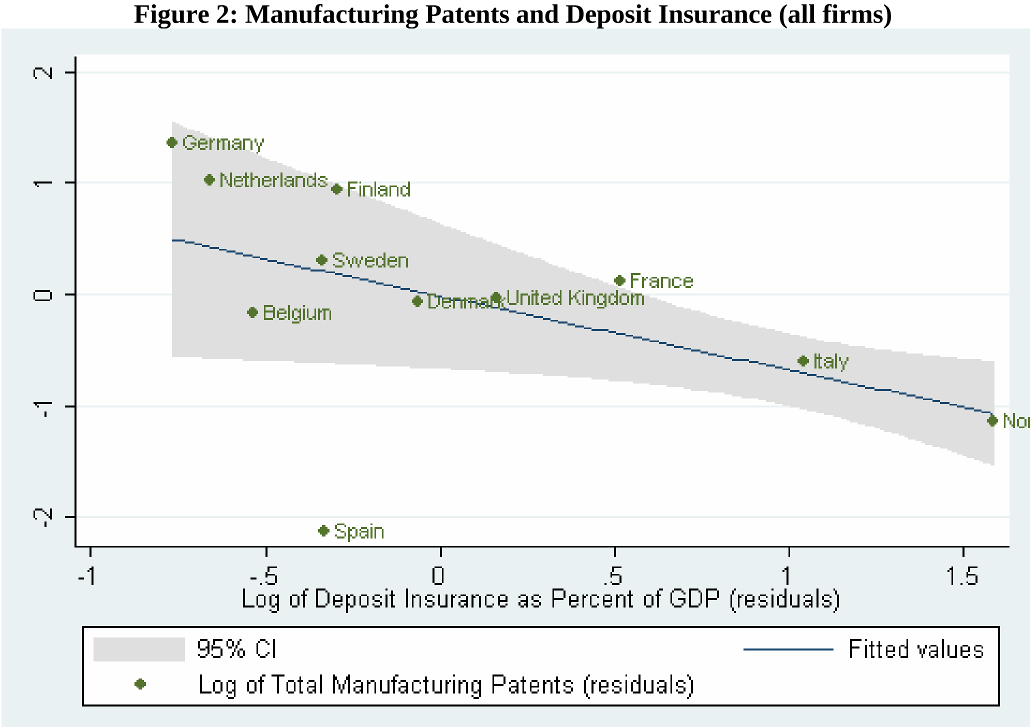


Figure 2: Manufacturing Patents and Deposit Insurance (all firms)



[56] Notes: The y-axis shows the residuals from a regression of the log of the total number of patents filed by manufacturing firms between 1997 and 2002 on log of the working population in 1997. The x-axis shows the residuals from a regression of the log of the number of credit institutions in 1997 (deposit insurance in Figure 2) on log of the working population in 1997. Confidence intervals are calculated using robust standard errors.

The policy relevance of this work is clear. There are ongoing attempts in the European Union to increase product market competition, with promises of more jobs and greater productivity. The Single Market Program in the 1990s reduced non-tariff trade barriers in manufacturing sectors between EU countries and the Lisbon Agenda in the current decade is an attempt to complete that process and extend it to service sectors. Also, European Commission anti-trust activity has increased greatly in the late 1990s with record fines for anti-competitive behaviour. Given that recent theory and evidence suggest that there can be both positive and negative effects on innovation from increased PMC, and given that external financial systems seem to be very important for innovation, it is desirable to know how increases in PMC interact with financial institutions.

This paper proceeds as follows: Section 2 discusses the theoretical background and shows how a complementarity between PMC and good financial intermediation can be derived theoretically; Section 3 describes the empirical specification, the product market reforms and the choice of financial institutional variables in more detail; Section 4 provides the main results and robustness checks; and a final section concludes.

2. THEORETICAL BACKGROUND

Recent models of step-by-step innovation incorporate the decreasing effect competition has on pre-innovation rents and predict a positive "escape competition" effect of PMC on innovation (Aghion, Harris, Howitt and Vickers 2001, Aghion, Howitt 2005). [57] This effect is prevalent in technologically advanced "frontier" sectors, where incumbent firms can achieve unconstrained monopoly status through innovating. In technologically "laggard" sectors firms cannot escape their competitors and PMC decreases *post*-innovation rents as well as *pre*-innovation rents, such that it discourages innovation (referred to as the "discouragement" or "Schumpeterian" effect). The average economy wide effect of increased PMC on innovation will depend on the proportion of frontier and laggard sectors and therefore on initial conditions (in the inverted-U of Aghion, Bloom, Blundell, Griffith and Howitt 2005 the effect of PMC on innovation depends on the initial levels of competition, for example).

[57] Early models emphasised the negative effects of competition on innovation (Salop 1977, Dixit and Stiglitz 1977, Aghion-Howitt 1992). Also "Deep pocket" (Schumpeter 1943) arguments predicted that increased PMC destroyed the funds available for research and development when firms faced external financing premiums.

The finance literature emphasizes the monitoring function of financial intermediaries in economies with information asymmetries between investors and firms. Monitoring by financial intermediaries is optimal over individual monitoring by investors as it avoids the duplication of monitoring costs and reduces problems of investors free-riding on other investors' monitoring effort. Efficient monitoring reduces agency costs by ensuring firms declare the returns from innovation (Diamond 1984, Aghion, Howitt, and Mayer-Foulkes 2005), or by evaluating the abilities of entrepreneurs to innovate (King and Levine 1993b). The research arbitrage condition in King and Levine (1993b) that is a building block of the Aghion-Howitt model predicts that where increased financial market efficiency lowers agency costs, innovation is increased: the more efficiently financial systems evaluate entrepreneurs/researchers the lower the cost of innovation.[58]

The intuition in this paper is that financial institutions associated with good monitoring increase innovation and thus the proportion of technological "frontier" sectors in the economy. This increases the extent to which PMC increases innovation in the economy. This prediction can be obtained by incorporating financial intermediation into a model of step-by-step innovation and product market competition. The following section demonstrates this.

2.1. Complementarity Between Competition and Financial Intermediation

This section describes a simple version of the multi-sector model of step-by-step innovation with entry (Aghion et al. 2004a).[59] Agency costs are incorporated following King and Levine (1993b), where individuals are able to perform research with ex-ante probability ϕ. The realization of this ability is private information that can be revealed by a financial intermediary for cost f. Better financial intermediation is modeled as a lower f and higher competition as a higher probability of entry p. What follows is as brief as possible, but for clarity it is necessary to repeat the key features of the Aghion-Howitt model.

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[58] As they note, the King and Levine 1993b model, although written with developing countries in mind, is applicable to developed countries with market or bank based systems, where monitoring and firm valuation is carried out by large financial conglomerates.

[59] The model presented here is the "escape-entry" version of the Aghion-Howitt framework. The same result is possible using the "escape-competition" version where PMC is modelled as a decrease in the cost structure of a competitive fringe that constrains each incumbent firm. This is presented in the Appendix.

As in Aghion-Howitt, a continuum of sectors, denoted by *i*, each containing one incumbent firm provide at time *t* an intermediate product of quality (productivity) A_{it} to be used in the production technology $y_t = \int_0^1 A_{it}^{1-\alpha} x_{it}^{\alpha} di$. Each firm supplies a quantity of the intermediate good, using a one-for-one production technology and pricing as an unconstrained monopolist, making profits equal to A_{it} .[60] Product market competition is modeled as a threat of entry by a foreign firm with exogenous probability, *p*. Each sector has an endowment of individuals that can be employed in either production or innovation. An innovation is an increase in the productivity of the intermediate good by a factor $\gamma > 1$, so that on innovating $A_{it} = \gamma A_{it-1}$. Following King and Levine (1993b), innovation requires two activities, the selection of researchers and the execution of research.[61] A financial intermediary will require a payment from the firm of f/ϕ labour units per successful researcher to break even.[62] The total cost (in labour units) of devoting n_{it} units of labour to research is therefore given by:

$$\gamma A_{it-1}(1 + f/\phi)n_{it} \tag{1}$$

where the factor γA_{it-1} captures the notion that the cost of innovation is increasing in the target quality level.

As in Aghion-Howitt (2005) the amount of labour devoted to research, *n*, increases the probability of successful innovation via a concave research production function: $\mu = g(n)$, $g'(n) > 0, g''(n) < 0, g(0) = 0$. The incumbent firm in each sector will choose the amount of labour to devote to research, or equivalently, will choose the optimal innovation probability to maximize expected profits subject to the cost of research:[63]

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[60] Strictly the profits equal δA_{it} , but the δ factor has no bearing on our result and is dropped from the analysis. See Aghion and Griffith (2005); by simple profit maximisation of $\pi_{it} = (p_{it} - 1)x_{it}$ the price charged for the good is equal to $1/\alpha$ the quantity supplied is such that $\partial y_t / \partial x_{it} = p_{it}$, so that $\delta = \left(\frac{1}{\alpha} - 1\right)\left(\frac{1}{\alpha^2}\right)^{-\frac{1}{1-\alpha}}$.

[61] Also described in Chapter 2 of Aghion and Howitt (1998), and similar to the costly state verification form in Aghion, Howitt and Mayer-Foulkes (2005).

[62] Break even evaluation price, *q*, for a financial intermediary when an individual incapable of research has no value (as a researcher) is given by: $\phi q + (1-\phi)0 = wf$, where *w* is the wage rate.

[63] As in Aghion and Howitt (2005), $g(n) = \sqrt{2n}$.

$$\max_{\mu_{it}}\left\{E\pi(\mu_{it})-\frac{1}{2}\gamma A_{it-1}(1+f/\phi)\mu_{it}{}^{2}\right\}, \tag{2}$$

where expected profits $E\pi(.)$ are a function of μ_{it}.

A technological frontier for intermediary goods increases the productivity of intermediary goods by the innovation factor γ each period, so that it moves each period from $\overline{A}_{t-1}$ to $\overline{A}_t = \gamma\overline{A}_{t-1}$. Three types of sectors, denoted by $j \in \{0,1,2\}$ exist. Sector type-*j* starts each period able to produce a good of quality $\overline{A}_{t-1-j}$. Types 0 and 1 innovate with probabilities μ_0, μ_1 respectively attaining a quality level of $\overline{A}_{t-j}$, type 2 sectors innovate automatically. As such, sector types 0 and 1 retain their type through innovation and type 2 sectors remain type 2 sectors. Each sector faces the same probability, *p*, that entry by a technologically advanced foreign firm occurs. In type-0 sectors the incumbents are advanced enough that if they innovate they retain the monopoly position even if entry does occur. In type-1 sectors the incumbents cannot compete with entrants even if they do innovate and earn zero profits when entry does occur.

The problem can be summarized by the following objective functions and first order conditions, for sector type-0 and type-1 respectively:

$$\max_{\mu_{0t}}\left\{\mu_{0t}\overline{A}_t+(1-\mu_{0t})(1-p)\overline{A}_{t-1}-\frac{1}{2}\gamma\overline{A}_{t-1}(1+f/\phi)\mu_{0t}{}^{2}\right\}$$

$$\mu_0=\frac{1}{(1+f/\phi)}\left(1-\frac{1}{\gamma}+\frac{p}{\gamma}\right)$$

$$\max_{\mu_{1t}}\left\{\mu_{1t}(1-p)\overline{A}_{t-1}+(1-\mu_{1t})(1-p)\overline{A}_{t-2}-\frac{1}{2}\gamma\overline{A}_{t-2}(1+f/\phi)\mu_{1t}{}^{2}\right\}$$

$$\mu_1=\frac{1}{(1+f/\phi)}(1-p)\left(1-\frac{1}{\gamma}\right) \tag{3}$$

An increase in PMC from an increase in the entry threat increases innovation effort in type-0 sectors (“the Escape-entry effect”) and decreases innovation effort in type-1 sectors (“the discouragement or Schumpeter effect”):

$$\frac{\partial \mu_0}{\partial p} = \frac{1}{(1+ f/\phi)}\left(\frac{1}{\gamma}\right) \qquad \frac{\partial \mu_1}{\partial p} = -\frac{1}{(1+ f/\phi)}\left(1-\frac{1}{\gamma}\right) \tag{4}$$

Higher agency costs, *f*, decreases effort in both types of sector and dampens the effect of PMC on effort in both sectors.

We see by inspection that:

$$\mu_0 > \mu_1 \text{ and therefore } \frac{1-\mu_1}{1-\mu_0} > 1,$$

$$\left|\frac{\partial \mu_0}{\partial f}\right| > \left|\frac{\partial \mu_1}{\partial f}\right| \text{ and both are negative.} \tag{5}$$

These properties follow from the fact that in this model there are greater incentives to innovate in frontier sectors than in laggard sectors, and will be useful in what follows.

Following Aghion et al. (2006), the short term aggregate effect of an increase in competition (an increase in the probability of entry) on aggregate innovation *I* is given by:

$$\left.\frac{\partial I}{\partial p}\right|_q = q_0 \frac{\partial \mu_0}{\partial p} + q_1 \frac{\partial \mu_1}{\partial p} = q_0 \frac{1}{1+ f/\phi}\left(\frac{1}{\gamma}\right) - q_1 \frac{1}{1+ f/\phi}\left(1-\frac{1}{\gamma}\right). \tag{6}$$

Where q_0 and q_1 are the proportion of frontier and laggard sectors respectively. This short term effect is exactly what we are interested in: it is the effect of an increase in competition, for a given initial condition, i.e. a given composition of frontier and laggard sectors (q_0 and q_1). This composition of sectors and the value of γ will determine whether (6) is positive or negative. Agency costs *f* will affect the composition of sectors and hence the value and sign of (6). In addition *f* will have a dampening effect on how innovation responds to competition through the $1/(1+ f/\phi)$ factor. We can investigate how (6) is affected by agency costs by taking the second derivative with respect to *f*. We assume that each country depends on their own financial intermediaries for the evaluation of researchers, and so carry out comparative statics across countries (this strong assumption is based on empirical observation and is discussed in section 3.1).

The second derivative is:

$$\left.\frac{\partial^2 I}{\partial f \partial p}\right|_q = -\left[q_0\left(\frac{1}{\gamma}\right) - q_1\left(1-\frac{1}{\gamma}\right)\right]\frac{1/\phi}{(1+f/\phi)^2} + \left[\frac{\partial q_0}{\partial f}\left(\frac{1}{\gamma}\right) - \frac{\partial q_1}{\partial f}\left(1-\frac{1}{\gamma}\right)\right]\frac{1}{1+f/\phi} \tag{7}$$

The first term of this expression is the dampening effect agency costs have on how each sector type reacts to changes in PMC. The second term is the composition effect agency costs have in shifting the proportion of frontier and laggard sectors and therefore the proportion of sectors where PMC has a positive or negative effect. We will show that this derivative is negative, meaning that high agency costs make the effect of PMC on innovation overall less positive.

Noting that foreign entry turns any sector into a type-0 sector, the steady state flow conditions for sector types 0, 1 and 2 respectively are:

$$\begin{aligned} pq_1 + pq_2 &= p(1-q_0) = (1-p)(1-\mu_0)q_0 \\ (1-p)(1-\mu_0)q_0 &= pq_1 + (1-p)(1-\mu_1)q_1 \\ (1-p)(1-\mu_1)q_1 &= pq_2 \\ q_0 + q_1 + q_2 &= 1 \end{aligned} \tag{8}$$

Solving these expressions yields:

$$q_0 = \frac{p}{p+(1-p)(1-\mu_0)} \tag{9}$$

$$\frac{q_1}{q_0} = \frac{(1-p)(1-\mu_0)}{p+(1-p)(1-\mu_1)} \tag{10}$$

We can make three observations that will tell us the sign of (7).

(i) The first term in (7) is negative. As $p<1$ and, from (5), $\mu_0 > \mu_1$, it follows from (10) that $q_0 > q_1$. Also, for any reasonable value of γ (that is, less than 2), $\left(1-\frac{1}{\gamma}\right) < \frac{1}{\gamma}$.

(ii) Agency costs reduce innovation effort μ_0, which from (9), and assuming $p<1$, means $\frac{\partial q_0}{\partial f} < 0$. Intuitively, high agency cost cause more sectors to fall out of type-0, a proportion given by $p<1$ of which return to type-0 through foreign entry, therefore in the steady state there are less type-0 sectors.

(iii) From (10) the ratio q_1/q_0 varies with agency costs as:

$$\begin{aligned}\frac{\partial}{\partial f}\left(\frac{q_1}{q_0}\right) &= \frac{\partial}{\partial f}\left[(1-p)\left(\frac{p}{1-\mu_0}+(1-p)\frac{1-\mu_1}{1-\mu_0}\right)^{-1}\right] \\ &= \frac{-(1-p)}{\left(\frac{p}{1-\mu_0}+(1-p)\frac{1-\mu_1}{1-\mu_0}\right)^2}\left[\frac{-p}{(1-\mu_0)^2}\left(-\frac{\partial\mu_0}{\partial f}\right)+(1-p)\frac{\partial}{\partial f}\frac{1-\mu_1}{1-\mu_0}\right]\end{aligned} \tag{11}$$

As $\frac{\partial\mu_0}{\partial f}<0$ the first term in the square bracket makes a positive contribution to the derivative of q_1/q_0. We can evaluate the second term as:

$$\frac{\partial}{\partial f}\frac{1-\mu_1}{1-\mu_0}=\frac{\frac{1-\mu_1}{1-\mu_0}\frac{\partial\mu_0}{\partial f}-\frac{\partial\mu_1}{\partial f}}{1-\mu_0}<0$$

That this expression is less than zero follows from (5). Therefore (11) is positive: $\frac{\partial}{\partial f}\left(\frac{q_1}{q_0}\right)>0$, increased agency costs increase the relative proportion of laggard sectors to frontier sectors (this is not sufficient on its own to give the sign of the second term in 7).

Point (iii) along with (ii) will give us the sign of the second term in (7) as follows. From (ii) we know that $\frac{\partial q_0}{\partial f}<0$ which means that, along with (iii) which states that $\frac{\partial}{\partial f}\left(\frac{q_1}{q_0}\right)>0$, increased agency costs decrease the number of type-0 sectors and at a greater rate than they (may) decrease the number of type-1 sectors. The number of type-1 sectors may increase or decrease, but this does not matter: the fact that $\frac{\partial q_0}{\partial f}$ is more negative than $\frac{\partial q_1}{\partial f}$ and the fact that $\left(1-\frac{1}{\gamma}\right)$ must be less than $\frac{1}{\gamma}$ for reasonable values of γ means that the second term in (7) is negative. Along with point (i) this means that $\left.\frac{\partial^2 I}{\partial f \partial p}\right|_q < 0$.

Therefore, higher agency costs decrease innovation effort and decrease the extent to which PMC increases aggregate innovation. This comes from two effects: one, agency costs decrease the proportion of frontier sectors relative to laggard sectors; and, two, agency costs dampen the elasticity of effort with respect to PMC in both types of sector, but more so in frontier sectors. Appendix 1 shows that we can reach the same prediction from other variants of the Aghion-Howitt model.

This is summarized in the following proposition.

Proposition: *Increased agency costs, f, (from poor financial intermediation) decrease the short term positive effect of product market competition, from increased entry threat p, on aggregate innovation I:*

$$\frac{\partial^2 I}{\partial f \partial p} < 0.$$

3. IDENTIFICATION, ESTIMATION AND MEASUREMENT

3.1. Identification

We are interested in the determinants of innovation in country, *c*, industry *i*, and year *t, and* particularly the role of both product market competition (PMC) and financial institutions and their interaction. We therefore consider a model of the form,

$$I_{cit} = f\left(PMC_{cit}, PMC_{cit} * FinancialInstitutions_c, FinancialInstitutions_c, v_{cit}\right) \quad (12)$$

Financial institutions are measured at the start of the sample period[64] and are assumed exogenous (i.e. they are not determined in response to immediate or anticipated changes in innovation and productivity in manufacturing).[65] It is also assumed that firms rely heavily on their domestic

[64] In the case of the number of credit institutions the variable is measured in 1997.

[65] It is important to note that innovative activity in the financial sector is not featured in this study. If it were it could be of concern that our financial institutions might react quite quickly to activity in that sector. They key assumption

financial systems for external finance (i.e. capital markets are closed). This is backed up by empirical observations. The reality about capital market openness, as noted in Carlin and Mayer (2003), is that there is actually very little cross-border, non-interbank lending in a sample of nine European countries, from as little as 1.6% of total non-bank loans in Spain to 9.9% in the UK. Raising equity finance has a similar domestic bias; it is a stylized fact in finance that domestic investors' equity portfolios are disproportionately weighted towards domestic stocks (Lewis 1999).[66]

Measures of PMC will be endogenous in their relationship with innovation in that innovations drive changes in competition and profitability. We use exogenous variation in PMC that arises due to product market reforms that were designed to increase competition:

$$PMC_{cit} = g\left(REFORMS_{cit}, \varepsilon_{cit}\right). \tag{13}$$

It is assumed that these reforms affect innovation only through their impact on PMC, i.e. $E\left[REFORMS'_{cit} v_{cit}\right] = 0$, and we will test this empirically.[67] This assumption also implies that country-sectors have not been targeted for product market reform because of anticipated changes in future productivity, but rather because they are in need of reform in that their initial levels of competition are low. The reforms used will be differential changes across country-industries, allowing us to control for unobservable differences across countries, across industries and across years using fixed effects. These reforms affect firms' behavior if there is a home bias in production, in that firms are located in the country where they wish to satisfy demand, at least to some extent. This is observed empirically in that the reforms have explanatory power in equation (13).

3.2. Empirical Specification

To investigate the relationship in 12 we will run the following Poisson regression:

$$PatentsPerFirm_{cit} = \exp\left(\gamma_1 PMC_{cit} + \gamma_2 PMC_{cit} * FIN_c + \eta_c + \eta_i + \tau_t + v_{cit}\right), \tag{14}$$

here is that financial institutions are at least slow moving in their response to what occurs in other parts of the economy.

[66] Bovenberg and Gordon (1996) develop a model of imperfect information that describes why capital is immobile between countries.

[67] In practice we will use the reforms to instrument both PMC and its interaction with financial institutions.

where FIN_c denotes financial institutions. The argument of (14) is the rate at which innovations occur.[68] The proposition in section 2 suggests that the cross-industry average effect of increases in PMC on the rate at which innovations occur should be more positive in countries with good financial institutions. This will be captured by the sign and statistical significance of $\hat{\gamma}_2$. Where FIN_c is increasing to indicate better institutions, a positive and significant $\hat{\gamma}_2$ coefficient indicates that the positive effect of competition is bigger with good financial institutions. The $\hat{\gamma}_1$ coefficient may be positive or negative, although we expect based on previous literature an positive average effect of PMC on innovation.

The dependent variable is the patents per firm in each country-industry-year. To control for time-invariant cross-sectional differences and measurement error in innovation and competition η_c contains country fixed effects and η_i contains industry fixed effects. τ_t contains time dummies to control for common shocks, and v_{cit} is a disturbance term. Patents are those filed at the European Patent Office (EPO) with the firm cited as applicant. Using patents per firm, rather than the sum of patents, controls in part for country-industry specialization. Any country or industry specific differences in firm size, and therefore patents per firm, will be controlled for by the country and industry fixed effects. Although the underlying dataset is at the firm level, variation in PMC occurs at the country-industry-year level and, therefore, regressions are run at that level.

The measure of PMC is one minus the ratio of value added minus labour costs over value added for country *i* and industry *j* (labour costs and value added are taken from national accounts data via the OECD's STAN database). As such it is one minus a weighted average of profitability for the entire country-industry, for each year. This gives an increasing measure of competition where one indicates perfect competition (zero profits). Similar profitability based measures have been used in Nickell (1996) and Aghion et al. (2005a).[69] Profitability based measures have the advantage over concentration based measures in that knowledge of the exact dimensions of the

[68] Given the non-negativity of the dependent variable and the skewness of the distribution of patents Poisson regressions are very widely used on the patent literature. See Aghion et al. (2005a) and others.

[69] We can think of this as an estimate of the mark-up or price cost margin (similar to a Lerner Index) if average costs are close to marginal costs. This is shown by Boone (2000) to be theoretically preferable to most other commonly used measures of competition, especially those based on market concentration or the number of firms, and it most closely corresponds to the parameter specified in theoretical models.

product market are not required. They have the disadvantage in that they are biased in the presence of non-constant returns to scale. To the extent that such bias is industry or country specific it will be captured by the industry and country fixed effects in our specification. Instrumentation of PMC will also mitigate for non-classical measurement error that may be caused by changes in technology and returns to scale. Capital costs are available for a sub-sample and are included as a robustness check. In theory, profitability measures could be calculated for each firm using the accounts data in Amadeus. However, the availability of this data is highly variable across firms and across time and therefore the OECD STAN database was considered a more reliable source of information.[70]

As mentioned, key to estimating the effect of competition on innovation in equation (14) is the use of product market reforms as exogenous variation in competition. The PMC variable is endogenous in that, among other reasons, patents grant monopoly rights and are therefore associated with higher average profitability. We use product market reforms such as the Single Market Program and antitrust action to instrument PMC and its interaction with FIN_c, following a control function approach that is common in the literature. This, in conjunction with the country and industry fixed effects, means that identification of the effect of PMC on innovation comes from differential changes in product market regulations across time, within countries, within industries. The reforms used are described in Section 3.4.

3.3. Firms and Patents

This paper uses patent applications as a measure of innovative activity. Although not a perfect measure of innovation in that many new techniques and tools that increase productivity do not require patents, patenting has been found to be associated with productivity growth and in our sample of countries is very closely related with measure of R&D expenditure at the industry level (see Chapter 1). Its advantage in this study is that we can observe it at the firm level across several countries for many firms, which is not true of declared research and development expenditure the accounting treatment of which differs largely across countries. The firm-patent dataset was constructed by the author by matching firms' accounts to patents filed at the European Patent Office (EPO). Firm names are obtained from the Amadeus accounts database and matched to patent applicants at the EPO, see Chapter 1 for a full description of the matching

[70] These variables, along with the others used in this study are summarized in Table A.1.

process. Amadeus gives us the industry sector of the firm and accounts information, the latter used in this study to identify incumbents by conditioning on listed firms.

The matching uses a target population of firms from several versions of the Amadeus dataset so that firms that may be filing accounts in early years but subsequently go out of business are not missed. The sample period in the current paper, 1995-2002, is within the time span for which we expect to have all firms active and eligible to be registered on Amadeus. To be registered on Amadeus usually requires the firm to be a registered legal entity, for example in the United Kingdom it means the firm is registered at Companies House. Any biases in estimation from differences in such rules across countries will be captured by fixed effects in our specification. The matching process was performed by standardizing firm names and applicant names and comparing them. The ability to do this is greatly improved by country specific knowledge leading to a 'researcher bias', the countries that we matched most successfully were those that we were most familiar with. Again, this will be controlled for by country fixed effects.

Our matching success rate in this sample period is extremely high. The total number of patents filed at the EPO by all corporate applicants in all sectors in the countries in our sample between 1995 and 2002 equals 291,723. Of these we successfully match at least one applicant to a unique company account for 242,593 patents; 161,308 of which match to manufacturing firms; 46,023 of which are filed by listed firms or their subsidiaries in the same sector and country and for which we have industry-wide profitability data. Therefore our final sample constitutes approximately one quarter of patenting activity we know to be carried out by manufacturing firms in these countries in this period.

I have selected only listed manufacturing firms that file patents, either directly or via a subsidiary (ownership information was constructed by Belenzon 2007). Listed manufacturing firms were the focus of ABBGH (2006). The theory is concerned with the effect of PMC on innovation by incumbent firms, the effect of PMC on entrants being likely rather different, and this seems an appropriate sample to focus on here. Table 1 column (1) lists the distribution of the 618 firms across the countries in the sample.[71] Column (2) shows the distribution of patent applications filed by these firms and their subsidiaries, where the subsidiary is in the same country and

[71] Each firm's country is its country of registration. For the vast majority of these firms their main listing is on a stock exchange in their country of registration. This is true in all cases except for one Finnish firm (London Stock Exchange) and one Italian firm (Berlin Stock Exchange). (The location of listing is not available from Amadeus for Spanish firms, British firms, one Italian firm, five Norwegian firms or two Swedish firms).

industry sector, and column (3) shows the distribution of the average patent per firm. There is considerable cross-country variation in this measure, with the value for Germany being much higher than in other countries for example. In the case of Germany this is likely due to a specialization in certain high patenting traditional manufacturing industries, as has been observed in the literature. This cross-country variation may be due to other differences in the enforcement of intellectual property rights. The country fixed effects and industry fixed effects should control for these differences. The variable summarized in column (3) is the key dependent variable used in this study. Conditioning on subsidiaries of listed firms in the same country gives a reasonable picture of firm innovative activity, however it is likely that with low technology transfer costs firms locate research and development overseas to take advantage of comparative advantages in skills (see Ekholm and Hakkala 2007 for a model of the location of production and research and development by multinationals). Therefore for robustness, I re-run my results using the number of patents filed by subsidiaries in the same industry as the parent, but located abroad, as the dependent variable. From column (4) we can see that this adds relatively few patents to the sample. One further concern may be firm birth and attrition, which may be correlated with changes in competition. Of the 618 firms in the sample, 529 are present for all 8 years, and the results of this paper are robust to conditioning on just these firms.[72]

Table 1: Listed Manufacturing Firms

Country	Number of firms (1)	Patents filed, including by subsids in same sector, same country (2)	Average of patents per firm (based on col. 2) (3)	Patents filed, including by subsids in same sector, in any country (4)	Average of patents per firm (based on col. 4) (5)
Belgium	16	927	5.78	1,024	6.18
Denmark	15	1,118	6.85	1,118	6.85
Finland	27	587	1.93	633	2.09
France	70	3,664	3.65	3,667	3.65
Germany	112	30,226	37.48	30,407	37.65
Italy	34	472	1.02	486	1.05
Netherlands	32	3,458	9.34	3,636	10.22
Norway	20	112	0.73	112	0.73
Spain	17	50	0.34	50	0.34
Sweden	25	469	2.05	470	2.06
United Kingdom	250	4,940	1.57	4,987	1.59
Total	618	46,023		46,590	

Notes: 86% of firms there for all 8 years (529 out of 618), 98% for 7 or more (606 out of 618).

[72] Average sizes of the firms in the sample and their distribution across countries are given in Table A.2.

3.4. Product Market Reforms

As discussed, measures of competition based on average profitability are endogenous in patent regressions. Finding exogenous variation in PMC is very difficult, especially at the industry level. I use European Commission anti-trust action and the European Union's Single Market Programme (SMP), the latter being an attempt to lower non-tariff barriers to trade within the EU. The remainder of this section describes each of these instruments in turn and the variables are summarized in Table 2.

Table 2: Product Market Reforms

Country	No. of country-sectors with high trade barriers affected by SMP (high tech.) (1)	No. of country-sectors with high trade barriers affected by SMP (traditional) (2)	No. of EC Anti-trust cases (3)
Belgium	3	1	4
Denmark	1	2	0
Finland	0	0	0
France	3	4	11
Germany	3	3	9
Italy	3	3	6
Netherlands	2	3	5
Norway	0	0	0
Spain	1	1	3
Sweden	0	0	4
United Kingdom	1	4	12
Total	17	21	54

Notes: In total there are 149 country-sectors in the sample. Non-SMP countries are Finland, Norway and Sweden.

The Single Market Programme (SMP) eradicated cross-country differences in product and service standards, administrative and regulatory barriers, VAT and capital controls which inhibited the free flow of goods, services and factors of production between EU countries. For our purposes we are most interested in the effect on trade barriers, i.e. the effect on product markets. To capture this impact and how it varies across country-industries we use a survey carried out before the program was implemented. Cecchini et al. (1988) surveyed 11,000 firms in different industries asking respondents to rate the current level of various barriers to trade. Based on this survey Buiges et al. (1990) identified 40 out of 120 industrial sectors that were deemed to be most sensitive to the program. They consulted individual country experts to confirm their findings and to add or remove sectors from the list according to country-specific circumstances. This resulted in a list of country-industries split into those with high trade barriers and those with medium trade barriers. I use country-industries that were deemed to have high trade barriers prior to the program, split by Buiges et al. (1990) into those that were high tech and those that were traditional sectors. From Table 2, column (1) and column (2) we can see that 38 out of the 149 country-industries in my sample were categorized as such. The SMP has been used as an instrument for competition at the country level in Griffith, Harrison and Macartney (2007) and at the industry level in Griffith, Harrison and Simpson (2006). Although the program started in 1992 most countries took some time to implement the reforms and did so at different rates, as recorded by The European Commission in its Internal Market Scoreboard[73]. Therefore I consider that country-sectors that were deemed to be affected by the reform were experiencing an ongoing period of reform in the late 1990s relative to those that were not affected. The variable I use is a vector of dummy variables that are interacted with the percentage of reforms actually implemented by each country, as recorded by the Internal Market Scoreboard from 1997 onwards, linearly interpolated between 1992 and 1997.

The European Commission (EC) has been increasingly active in anti-trust actions in the late 1990s. The variable I use I have constructed from cases described on the EC website.[74] Cases that involve actual fines implemented or action by alleged violators of anti-trust legislation to avoid further proceedings are included. There were 54 such cases in our sample and their distribution across countries is given in Table 2, column (3). The EC website gives the firms involved and their industrial sector of activity. I construct the variable so that for each case it is one in the country-industry sector after the date action is taken and zero before hand, indicating a permanent increase in competition after EC action. The variable is cumulative in that the number of cases are added up if there are several in a country-industry. It is assumed that anti-trust action is exogenous in that the EC does not target sectors because it believes there will be future changes in productivity or innovation.

Table 3, column (1) shows the results of the first stage regression of our measure of competition on the three product market reform variables. Column (1) shows that the excluded instruments have explanatory power in that they are statistically significant and have a partial R-squared of 2 percent. The signs on the SMP High Barriers high tech sectors variable and the EC anti-trust variable are positive indicating that these reforms were associated with increases in competition, whereas the sign on the SMP High Barriers traditional sectors variable is negative. As mentioned

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[73] The scoreboard is available at http://europa.eu.int/comm/internal_market/score/index_en.htm.

[74] Cases are described at http://ec.europa.eu/comm/competition/antitrust/cases/index.html.

we aim to instrument both the linear PMC variable and its interaction with FIN_c in equation (14). To aid this we use interactions of the reform variables with the assumed exogenous FIN_c variables. Columns (2) and (3) show the two first stage regression that will be run when using $FIN_c = Credit\ Institutions\ per\ Capita$ and columns (4) and (5) show the two first stage regressions that will be run when using $FIN_c = Deposit\ Insurance$. We can see in both cases the use of interacted variables in this way increases the amount of variation in PMC that we can explain, indicated by higher R-squared measures.

Table 3: Product Market Reforms and Competition

Dependent variable:	1-Profitability	1-Profitability	1-Profitability * No. of Credit Institutions per Capita	1-Profitability	1-Profitability * Deposit Insurance
	(1)	(2)	(3)	(4)	(5)
SMP High Barriers (high tech)	0.072	0.074	0.002	0.016	-0.257
	[0.027]***	[0.043]*	[0.002]	[0.031]	[0.106]**
SMP High Barriers (traditional)	-0.034	-0.023	0.001	-0.046	0.048
	[0.019]*	[0.022]	[0.001]	[0.022]**	[0.043]
EC Anti-Trust Action	0.026	0.039	0.001	0.064	0.082
	[0.013]*	[0.016]**	[0.001]**	[0.025]**	[0.042]**
SMP High Barriers (high tech) * No. Of Credit Institutions per Capita		-0.067	0.036		
		[0.760]	[0.031]		
SMP High Barriers (traditional) * No. Of Credit Institutions per Capita		-0.312	-0.080		
		[0.380]	[0.022]***		
EC Anti-Trust Action * No. Of Credit Institutions per Capita		-0.425	-0.019		
		[0.499]	[0.021]		
SMP High Barriers (high tech) * Deposit Insurance				0.029	0.154
				[0.012]**	[0.044]***
SMP High Barriers (traditional) * Deposit Insurance				0.007	-0.073
				[0.006]	[0.016]***
EC Anti-Trust Action * Deposit Insurance				-0.018	-0.012
				[0.009]**	[0.021]
Output Gap	-0.002	-0.002	0.000	-0.001	-0.009
	[0.003]	[0.003]	[0.000]	[0.003]	[0.008]
Constant	0.616	0.616	0.02	0.617	1.718
	[0.020]***	[0.020]***	[0.001]***	[0.019]***	[0.062]***
Country fixed effects	Yes	Yes	Yes	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes
P-value for F-test of excluded instruments	0.0020	0.0036	0.0001	0.0004	0.0000
Partial R-squared of excluded instruments	0.02	0.03	0.03	0.05	0.07
Observations	1177	1177	1177	1177	1177

Notes: OLS regression. The time period is 1995 to 2002 inclusive. Observations are country-industry-years. Robust standard errors are in brackets.

3.5. Financial Institutions

This section motivates the choice of *the number of credit institutions per capita* and *the maximum amount of a bank deposit covered by insurance as a ratio to GDP per capita* as measures of the effectiveness of financial systems to reduce agency costs. It is difficult to measure the extent to which financial systems provide good monitoring of investments, and the motivation of these measures draws heavily on evidence from existing literature.

There is much debate as to which financial systems may promote effective monitoring and an efficient allocation of capital. Firstly, do bank-based or market-based systems provide better information for investors? Traditionally the theoretical finance literature has asserted that bank-based systems have a comparative advantage in monitoring over market systems. Securities markets suffer from investors free-riding on other investors' information gathering (Stiglitz 1985) and adverse selection driving up the cost of finance for all firms (Akerloff 1970). On the other hand securities provide liquidity enabling investors to manage risk and crystallize gains and losses sooner rather than later. In developing countries it appears that whether finance is bank-based or market-based does not matter for growth (see Levine 2005). Furthermore, there appears to be complementarities between the two and evidence suggests that greater stock market development promotes greater bank lending (as discussed in Demirguc-Kunt and Levine 1996).[75] Institutional measures of stock market efficiency are not readily available and therefore the current study uses measures that are more bank based than market based.[76] The results are not intended to imply that bank based systems are more important, but rather the measures used are proxies for a financial environment that promotes good monitoring. It is fair to say that there is theoretical and empirical evidence of a bias in financing innovation towards equity rather than debt (Hall 2002, Aghion et al 2004b). The assumption in the current paper is that financial systems that promote good monitoring mitigate problems of adverse selection and reduce the cost of finance faced by firms regardless of the exact financial instrument used.[77]

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[75] This true in our sample of ten countries in that the correlation coefficient of stock market capitalization as a ratio of GDP and total bank credit as a ratio of GDP measured in 1995 is 0.64.

[76] Measures of the size of stock market and bank credit markets are available from Beck, Demirguc-Kunt and Levine (2000). These measures are not really institutional in nature and are likely endogenous in that specific types of finance, or the total amount of credit in the economy may precede future increases in growth.

[77] Indeed there is some view that stock market investors free-ride on information gathered by banks, see page 26 of Levine 2005 for a discussion.

Given that we are restricted to using bank based institutional measures the second question is: which financial institutions or organizational characteristics promote good monitoring by banks? There is a reasonable consensus that fragmented banking systems are associated with better monitoring and a more efficient allocation of capital. Firstly, small banks have a comparative advantage in lending based on 'soft' rather than 'hard' information. The idea being that in large organizations the justification for lending has to be passed through the hierarchical structure and this communication is much easier if the information is based on hard verifiable data such as financial ratios. There is evidence that small banks are more likely to lend to informationally difficult clients, such as small firms lacking full financial accounts (Berger et al. 2005). It is likely that such issues are also important in the case of innovative firms, where investment is by definition in intangibles. Secondly, an economy dominated by small lenders may be better at enforcing hard budget constraints. For large banks it is ex-post efficient to re-finance bad projects that the banks have already sunk capital into. Small banks have insufficient capital for this to be a problem, lenders are forced to re-finance with a new lender at each stage of the project. This capital starvation of bad quality projects, alleviates adverse selection problems and reduces monitoring costs for investors as they are less likely to lend to bad projects (Dewatripont and Maskin 1995, Akerloff 1970). There is empirical evidence that fragmented banking systems promote industry growth in developed countries (Cetorelli and Gambera 2001), particularly in industries with inherent informational asymmetries (Carlin and Mayer 2003). Concentration measures are highly correlated with country size (small countries have less banks) and therefore, to avoid picking up market size effects, I use for my first measure of institutional structure: *the number of credit institutions per capita*.[78] This measure is related positively to cross-country measures of patenting in our sample, as we have already seen in Figure 1, and the relationship is robust to controlling for industry specialization by way of three-digit industry fixed effects, as presented in column (1) of Table 4. Although this cross-country association could be driven by other country specific factors it is at least consistent with the idea that these institutions have an association with innovation rates in a way that we might expect.

[78] Cetorelli and Gambera 2001 use concentration measures instrumented by market size measures such as GDP and population, and by legal institutions. Carlin and Mayer 2003 use the same measure un-instrumented. My results are robust to using such measures, available from the author on request.

Table 4: Financial Institutions and Innovation in Manufacturing (all firms)

Dependent variable:	Patent Applications		
	(1)	(2)	(3)
Log of no. of Credit Institutions per Capita	1.347		1.011
	[0.307]***		[0.385]***
Log of Deposit insurance		-1.043	-0.421
		[0.167]***	[0.188]**
	-0.284	1.074	0.027
Log of Working Population at 1997	[0.307]	[0.151]***	[0.375]
Constant	-27.03	-8.636	-22.565
	[15,302.821]	[1.232]***	[285.488]
3 Digit Industry fixed effects	Yes	Yes	Yes
Observations	947	947	947

Notes: Poisson regression. Observations are country-3 digit industries. The time period is 1997 to 2003 inclusive. The dependent variable is the sum of patent applications in each country-manufacturing industry across the time period divided by the population. Robust standard errors are in brackets clustered at the country level.

Although institutional in nature and likely to be slower moving than market outcome measures such as the amount of credit in the economy, the number of credit institutions itself may be endogenous in that it changes with anticipated changes in industrial productivity. As discussed by Cetorelli and Gambera (2001) there are reasons why regulators may control banking structure that are nothing to do with industry growth, however concerns remain. The Cetorelli and Gambera (2001) approach is to instrument banking concentration with legal institutional variables, but this is problematic for us as we use patents as our dependent variable and the value of a patent is likely to vary with the cost of suing for patent infringement and therefore with legal institutions (we later ensure that our result is robust to controlling for this). The approach taken here is to ensure the result is robust to using another measure of financial institutions that is likely to be even slower to respond to changes in manufacturing productivity. This measure is: *the maximum amount of a bank deposit covered by insurance as a ratio to GDP per capita*. The purpose of deposit insurance is to prevent runs on banks, but there is much debate as to its desirability. As emphasized by Diamond (1984) there is a delegation cost incurred by investors in entrusting monitoring to financial intermediaries: investors are required to monitor the intermediary and to promote efficient lending it is desirable that they do so. Knowing that their deposits are insured reduces their incentive to do so. Indeed there is microeconomic evidence from US states that deposit insurance schemes are associated with indiscriminate credit expansions, poor productivity growth and bank failures (Dehejia and Lleras-Muney 2003, Wheelock and Wilson 1995). Of course a country with a deposit insurance scheme could set such policy in response to a poorly performing financial sector, either way it is assumed here that deposit insurance schemes are indicative of a financial system that does not monitor investments effectively. In our sample, as we have seen in Figure 2, deposit insurance is negatively related to cross-country measures of patenting, and this is robust to controlling for three digit industry fixed effects as in column (2) of Table 4.

Both measures are obtained from the DICE database available at the CESifo website.[79] They are listed in Table 5 for each country and we can see that they vary considerably across the ten countries in our sample.[80] In fact there is enough variation in the variables to separately identify their effects on country-industry innovation by including both in a cross-country regression as in column (3) of Table 4. Deposit insurance does not vary for the countries in the sample over the time period. The number of credit institutions does vary during the period, for most countries it decreases due to consolidation in the banking sector, as discussed in Walkner and Raes (2005). We may be concerned that this variation is caused by unobservable factors that also affect innovation and, therefore, I use the value at 1997, which is as close to the start of the sample period (1995) for which I have data. The results are robust to dropping the first two years of the sample, available from the author on request.[81]

Our interpretation of the variables is consistent with Bond, Harhoff and Van Reenen (1999) which finds that firms in the United Kingdom are more financially constrained than those in Germany, in that cash flow is a predictor of the R&D participation decision (although not the level of spending thereafter). Bond, Harhoff and Van Reenen (1999) states that the exact source of these constraints is unclear. The idea that United Kingdom firms are more financially constrained than those in Germany is consistent with the measures in Table 5 in that the United Kingdom has less credit institutions than Germany and a higher level of deposit insurance.

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[79] See http://www.cesifo.de/pls/diceguest/search.create_simple_search_page

[80] The number of credit institutions, concentration measures and the number of local banking units come originally from the European Commission study by Walkner and Raes (2005). Credit institutions are defined by the European Central Bank as any institution covered by the definition contained in Article 1(1) of Directive 2000/12/EC, as amended. Accordingly, a credit institution is "(i) an undertaking whose business is to receive deposits or other repayable funds from the public and to grant credits for its own account; or (ii) an undertaking or any other legal person, other than those under (i), which issues means of payment in the form of electronic money." The most common types of credit institutions are banks and savings banks. Deposit insurance information comes originally from the World Bank.

[81] Similar results are also found if we let the number of credit institutions per capita vary over time, while controlling for its direct effect by including it as a linear term. Also, consistent results are obtained if we simply split the sample into two: high credit institutions and low credit institutions. These results are available from the author on request.

Table 5: Financial Institutions

Country	No of Credit Institutions (per thousand people)	Deposit Insurance
	(1)	(2)
Belgium	0.02	0.77
Denmark	0.06	1.15
Finland	0.10	0.91
France	0.03	2.70
Germany	0.06	0.78
Italy	0.02	4.58
Netherlands	0.06	0.72
Norway	0.05	5.81
Spain	0.02	1.11
Sweden	0.04	0.92
United Kingdom	0.01	1.89

Notes: Values at 1997 for column (1). Deposit insurance is time-invariant in this period. Deposit insurance is the maximum balance amount insurable divided by GDP per capita.

4. RESULTS

4.1. Main Results

The results for the regression described in equation (14) are reported in Table 6, for an unbalanced panel of 149 country-2 digit industries over 8 years. The dependent variable is the average number of patents filed by listed firms and their subsidiaries in each country-industry-year. Robust standard errors are in brackets, clustered at the country level because the measures of financial institutions vary only across countries. Our measure of competition is 1-Profitability for country *c*, industry *i* and year *t*, and is increasing with greater competition. Country and industry fixed effects control for cross-sectional differences, and year dummies for common macroeconomic shocks. The difference of output from trend is included as a control variable although it is never significant, perhaps as the sample does not quite cover one business cycle.

Column (1) shows the results of the regression with the restriction $\gamma_2 = 0$, that is the average linear effect of PMC on innovation. Column (2) control for the endogeneity of the 1-Profitability variable by including the residuals from the first stage regression listed in column (1) of Table 3 as a control function.[82] The control function is statistically significant indicating that the 1-Profitability is indeed endogenous. Its sign is negative which is as expected as patents grant

[82] The results are robust to using two control functions together, one from a linear PMC first stage and one from a PMC interacted with financial institutions first stage, as in Aghion et al. (2006).

monopoly rights to firms and are associated with greater profitability, therefore instrumentation removes a negative bias from the patenting, competition relationship. We can see that the $\hat{\gamma}_1$ is both positive and statistically significant, consistent with the Nickell (1996) and Blundell et al. (1999) results that on average increased PMC increases innovation. As a test of the validity of the exclusion restrictions for the product market reform variables the P-value for the Hansen overidentified test is 0.6172, meaning that the exclusion restrictions cannot be rejected.[83] Column (3) now investigates how the effect of PMC on manufacturing innovation rates depends on financial institutions. $\hat{\gamma}_2$ is positive and significant, meaning that the effect of PMC on innovation is greater in countries with a large number of credit institutions per capita. Column (4) controls for the endogeneity of our measure of PMC by instrumenting both the linear PMC term and its interaction. This is performed by running the two first stage regressions listed in columns (2) and (3) of Table 3 and including the residuals from each as two separate control functions. The result is robust to this instrumentation. The median effect in column (4) is positive with a value of 7.685.[84] Column (5) investigates the effect of our alternative measure of financial institutions: deposit insurance. As discussed deposit insurance may reduce the incentives for good monitoring of investment projects, reducing steady state innovation rates and therefore the positive effect of PMC on innovation. Column (5) shows that the interaction is negative as expected and column (6) indicates that this is robust to instrumentation using the residuals from the two first stage regressions in columns (4) and (5) of Table 3 as control functions. The median effect from column (6) is 0.122.[85]

What is the economic significance of these results? Using the estimates in column (4) the effect of a one percentage point increase in competition in the United Kingdom, which has a low 0.01 credit institutions per thousand people, is a 3.58 percent *decrease* in patenting per firm.[86] For

[83] This was carried for the OLS regression of the log of patents per firm on the explanatory variables, as opposed to the Poisson specification for the which the test is more difficult to perform.

[84] Coefficients are semi-elasticities. The median effect for column (4) equals -7.333+(375.464*0.04), where 0.04 is the median of the number of credit institutions per capita in our sample. The mean is also equal to 0.04, but I chose to quote median effects as the distribution of deposit insurance is very highly skewed, with only three values greater than the mean.

[85] The median effect for column (6) equals =5.466+(-4.814*1.11), where 1.11 is the median of deposit insurance measure for our sample.

[86] This is calculated from [-7.333+375.464*0.01]*0.01*100, noting that the coefficients in a Poisson regression are semi-elasticities.

Germany, which has a high 0.06 credit institutions per thousand people, the same increase in competition would *increase* average patenting per firm by 15.19 percent.[87]

Table 6: Competition, Financial Institutions and Innovation

Dependent variable:	Patents per firm					
	(1)	(2)	(3)	(4)	(5)	(6)
1-Profitability	0.823	9.058	-6.88	-7.333	3.576	5.466
	[0.989]	[4.303]**	[3.069]**	[3.406]**	[1.776]**	[4.858]
1-Profitability *No of Credit Institutions per Capita			139.324	375.464		
			[46.637]***	[68.329]***		
1-Profitability *Deposit Insurance					-2.235	-4.814
					[1.686]	[2.091]**
Control Function		-8.153		1.957		-2.715
		[3.830]**		[4.427]		[5.134]
Credit Institutions Interaction Control Function				-262.958		
				[92.176]***		
Deposit Insurance Interaction Control Function						3.294
						[2.515]
Output Gap	0.049	0.079	0.017	0.000	0.037	0.011
	[0.044]	[0.044]*	[0.047]	[0.048]	[0.047]	[0.055]
Constant	-0.525	-6.065	1.482	-3.797	1.634	4.59
	[1.094]	[3.104]*	[1.091]	[2.373]	[1.914]	[2.127]**
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Hansen test of exclusion restrictions (P-value)		0.6172		0.0058		0.0559
Observations	1177	1177	1177	1177	1177	1177

Notes: The time period is 1995 to 2002 inclusive. Observations are country-industry-years. Robust standard errors are in brackets. They are clustered at the country level as the financial institutions are invariant across industries and years. ***, **, * indicates statistical significance at 1%, 5% and 10% respectively.

One concern with the results is that firm birth or death that affects average patenting in each country-industry and is correlated with changes in product market competition may be driving the results. Such firm attrition, although perhaps a consequence of competition, would reflect a different dynamic than that of the effect of competition on innovation incentives by incumbents that motivates this work. Therefore we now repeat the results for a balanced panel of firms. The results for the 1080 observations for which we observe at least one firm in each country-industry for the entire sample period are presented in Table 7 and are consistent with those for the unbalanced panel. The interaction between PMC and the number of credit institutions per capita

[87] The United Kingdom and Germany have credit institutions per capita approximately one standard deviation either side of the mean; the United Kingdom's value is the lowest in the sample and the only value to have an estimated negative effect of PMC on innovation.

is positive and significant (column 4) and the interaction between PMC and deposit insurance is negative and significant (column 6).

Table 7: Competition, Financial Institutions and Innovation (balanced panel)

Dependent variable:	Patents per firm					
	(1)	(2)	(3)	(4)	(5)	(6)
1-Profitability	1.092	7.287	-8.873	-27.914	3.683	4.537
	[1.092]	[5.821]	[4.425]**	[8.306]***	[1.711]**	[5.632]
1-Profitability *No of Credit Institutions per Capita			165.773	421.057		
			[63.556]***	[152.731]***		
1-Profitability *Deposit Insurance					-2.185	-5.162
					[1.522]	[2.245]**
Control Function		-6.233		18.618		-1.751
		[5.282]		[9.320]**		[5.228]
Credit Institutions Interaction Control Function				-255.054		
				[169.049]		
Deposit Insurance Interaction Control Function						3.690
						[2.432]
Output Gap	-0.002	0.036	-0.027	-0.088	-0.018	-0.06
	[0.049]	[0.060]	[0.058]	[0.088]	[0.052]	[0.074]
Constant	-1.324	-5.463	1.693	8.444	0.936	5.296
	[1.219]	[3.994]	[1.618]	[2.645]***	[1.935]	[2.097]**
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1080	1080	1080	1080	1080	1080

Notes: The time period is 1995 to 2002 inclusive. Observations are country-industry-years. Robust standard errors are in brackets. They are clustered at the country level as the financial institutions are invariant across industries and years. ***, **, * indicates statistical significance at 1%, 5% and 10% respectively.

4.2. Robustness and institutions

It is clear from the specification in Section 3 that any country specific factor that increases the cost of innovation and/or patenting may affect the PMC-innovation relationship. Where such a factor is institutional in nature we may be concerned that it is correlated with financial institutions and thus driving our results. One obvious contender is labour market institutions, which have considerable variation across the countries in our sample. Although the theoretical impact of labour market institutions on innovation is equivocal in that rigid labour markets may increase workers' commitment to invest in firm specific innovation but at the same time may increase the adjustment costs for firms (see Chapter 4 for a discussion and evidence of both of these effects from employment protection legislation), there is considerable evidence that labour market institutions affect the impact of changes in product market competition on outcomes such as employment (see Griffith, Harrison and Macartney 2007, Nicoletti and Scarpetta 2005 and the references therein) and productivity (see Aghion, Burgess, Redding, Zilibotti 2003). To ensure my results are not driven by employment protection legislation (EPL), I take the regressions from columns 4 and 6 of Table 6 and include an interaction of PMC with a widely used measure of EPL. We instrument each of the PMC term, the PMC*No. of Credit Institutions per Capita term and the PMC*Employment Protection Legislation term, using a control function for each with interactions of product market reforms with EPL as additional instruments. The results are presented in columns 1 and 5 of Table 8. The EPL variable is time-invariant and the country fixed effects control for its direct effect on innovation. We can see that the results are robust to this control. Similar results are found using collective bargaining coverage as an alternative measure of the labour market environment, as presented in columns (2) and (6).

Another concern specifically connected with our use of patents as a measure of innovation is the extent to which intellectual property protection varies across countries. All patents used in this study are filed at the European Patent Office, providing patent holders with Europe wide protection. One advantage of using only EPO patents is that all patents at the EPO carry the same legal protection. However, patent holding firms are required to make claims on patent infringement through the courts in the country where the defendant is domiciled. To the extent that this is the same country as that of the patent holder this leads to a potential source of heterogeneity in patent value across countries in our sample. The cost of suing for patent infringement will be higher in countries with slow legal systems and therefore the value of holding patents lower, and this characteristic of legal institutions may be related to financial institutions. Using a methodology developed in Djankov et al. (2003) the Doing Business report constructs a cross-country measure based on a hypothetical breach of contract case and survey responses from local litigators.[88] The measure is the cost of suing as a percentage of the claim amount and is listed for the countries in our sample in Table 9 along with a similar measure based on the average number of days in court for the hypothetical case. Vaver (1999) notes that the Italian and Belgian courts are notoriously slow and this is reflected in the measure in Table 9 in that Italian courts are most expensive and the slowest in our sample, and Belgium courts are fifth slowest, but are actually quite cheap.[89] This measure is time-invariant and we can interact it

[88] See http://www.doingbusiness.org/ExploreTopics/EnforcingContracts/ for data and exact methodology.
[89] Vaver also notes that patent infringers pursue various strategies to force litigation to occur in a slow court, often referred to as “deploying the Belgian or Italian torpedo”. Such factors cannot be controlled for here. Again some

with our PMC variable and let country fixed effects control for its direct effect on patenting per firm.

Table 8: Robustness, Other Institutions

Dependent variable:	Patents per firm							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1-Profitability	-12.239	-6.323	-6.639	-0.587	10.784	9.906	14.425	18.289
	[7.677]	[10.774]	[4.602]	[5.653]	[6.814]	[8.689]	[4.192]***	[9.775]*
1-Profitability * No of Credit Institutions per Capita	302.088	283.405	314.229	354.171				
	[73.517]***	[78.944]***	[106.273]**	[59.261]***				
1-Profitability * Deposit Insurance					-7.545	-8.993	-5.671	-4.697
					[1.550]***	[1.582]***	[2.328]**	[1.848]**
1-Profitability * Employment Protection Legislation	2.178			3.056	2.759			4.262
	[2.311]			[1.839]*	[1.821]			[5.438]
1-Profitability * Collective Bargaining Coverage		-0.008		-0.127		0.074		-0.207
		[0.123]		[0.079]		[0.087]		[0.261]
1-Profitability * Average Proportional Legal Costs			-0.141	-0.107			-0.187	-0.271
			[0.123]	[0.106]			[0.094]**	[0.138]**
Control Function	1.536	1.18	4.512	-0.158	5.48	7.446	-8.526	-3.115
	[3.784]	[104.942]	[4.437]	[4.899]	[4.584]***	[3.756]***	[4.367]*	[4.710]
Credit Institutions Interaction Control Function	-183.253	-158.701	-216.248	-234.206				
	[83.919]**	[4.704]	[106.446]**	[93.005]**				
Deposit Insurance Interaction Control Function					-14.49	-13.578	4.037	2.776
					[2.186]**	[1.987]***	[1.639]**	[2.674]
Output Gap	0.01	0.013	-0.011	-0.005	0.015	-0.013	0.02	-0.027
	[0.044]	[0.048]	[0.069]	[0.052]	[0.047]	[0.055]	[0.056]	[0.070]
Constant	-2.844	-1.768	-1.123	-4.35	0.396	3.903	2.225	3.908
	[2.366]	[3.143]	[2.974]	[2.501]*	[1.976]	[2.899]	[3.360]	[2.027]*
Control functions for "other institutions"	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1177	1177	1177	1177	1177	1177	1177	1177

Notes: The time period is 1995 to 2002 inclusive. Observations are country-industry-years. Robust standard errors are in brackets. They are clustered at the country level as the financial institutions are invariant across industries and years. ***, **, * indicates statistical significance at 1%, 5% and 10% respectively.

appeal is made to home bias, in that when seeking intellectual property protection, incumbent firms expect infringement and litigation more likely to occur in their domestic countries (or rather if this were not the case, then there would be no concern that this may drive our results).

Columns (3) and (7) of Table 8 show that the reaction of patenting to increased PMC is dampened in countries with expensive courts and this interaction is statistically significant in column (7), although not in column (6). Columns (3) and (7) show that the key results of our paper are robust to including this interaction. Similar results hold using the average number of days in court.

Finally, columns (4) and (8) of Table 8 show that our key results are robust to the inclusion of interactions of PMC with employment protection, collective bargaining and legal costs together, although there is not enough variation in the data to instrument all of the control interactions simultaneously.

Table 9: Legal Institutions

Country	% Cost of Claim	No. of days in court
Belgium	16.6	505
Denmark	23.3	380
Finland	10.4	235
France	17.4	331
Germany	11.8	394
Italy	29.9	1210
Netherlands	24.4	514
Norway	9.9	310
Spain	17.2	515
Sweden	31.3	508
United Kingdom	23.4	404

4.3. Robustness, other

This section takes the results from column (3) and (4) of Table 6 and exposes them to some further robustness checks, the results of which are presented in Table 10. One concern is the use of the average number of patents per firm as the dependent variable. This may capture differences in average firm size rather than actual patenting intensity, differences which may be related to financial institutions. Beck, Demirguc-Kunt, Maksimovic (2003) describes how average firm size might be related to financial institutions, although the theoretical relationship is ambiguous: with poor financial institutions average firm size is large as firms need to rely on internal capital markets; on the other hand large firms are difficult to monitor and this requires good financial institutions. They find more evidence for the latter effect: with good financial institutions, firms tend to be larger. It is difficult to see exactly how such a bias could drive our results, given that identification comes from differential changes in product market competition interacted with time-invariant financial institutions, nevertheless I ensure that the key result is robust to using the sum of patents in each country-industry-year and this is presented in columns (1) and (2) of Table 10.

Table 10: Further Robustness

Dependent variable:	Sum of patents	Sum of patents	Citation weighted patents per firm	Citation weighted patents per firm	Patents per firm	Patents per firm
	(1)	(2)	(3)	(4)	(5)	(6)
1-Profitability	-6.877	-7.005	-8.927	-6.95		
	[3.104]**	[3.752]*	[5.051]*	[7.013]		
1-Profitability *No of Credit Institutions per Capita	146.724	284.351	191.479	308.555		
	[42.631]***	[93.021]***	[80.057]**	[89.015]***		
1-Profitability(including capital costs)					-2.691	-10.568
					[0.835]***	[2.803]***
1-Profitability(including capital costs)*No of Credit Institutions per Capita					67.347	221.661
					[17.698]***	[53.390]***
Control Function		0.730		-1.325		8.414
		[5.255]		[7.441]		[3.211]***
Credit Institutions Interaction Control Function		-150.276		-126.862		-168.045
		[118.587]		[128.297]		[61.004]***
Output Gap	-0.041	-0.047	0.028	0.032	-0.06	-0.049
	[0.045]	[0.047]	[0.067]	[0.060]	[0.048]	[0.052]
Constant	3.347	0.186	1.507	-2.554	-0.937	0.66
	[1.132]***	[2.921]	[1.397]	[3.937]	[0.648]	[1.246]
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1177	1177	1177	1177	824	824

Notes: The time period is 1995 to 2002 inclusive. Observations are country-industry-years. Robust standard errors are in brackets. They are clustered at the country level as the financial institutions are invariant across industries and years. ***, **, * indicates statistical significance at 1%, 5% and 10% respectively.

A second concern is that the measure of patents filed does not capture the fact that some patents are much more important or valuable than others and therefore constitute a much greater investment by the firm. The common way in the literature to control for this is to weight patents by the number of citations they have received. The reason I have not done this in the main results is that, given our sample period, patents in later years are relatively new and have many less citations than those in earlier years. This trend should be adequately controlled for by the year dummies and I present the key regressions in columns (3) and (4), using citations weighted patents per firm as the dependent variable. The results are robust to this in that the positive effect of competition on innovation is higher in countries with a large number of credit institutions per capita.

Another concern addressed here is that the measure of product market competition used so far uses a mark-up over labour costs alone, as the capital stock can only be estimated for a much smaller sample. As discussed, the measure of competition will be biased in non-constant returns to scale and we may be concerned that this bias may be correlated with changes in technology as observed through patenting. This will be controlled for to some extent by instrumentation, but concerns remain and such biases may be larger when capital costs are ignored. Therefore I re-run the key regression using a measure of competition that includes capital costs from an estimated capital stock and the US interest rate as a proxy for the cost of capital. The results for the sub-sample for which this is possible are reported in columns (5) and (6). The key result that competition has a more positive effect on innovation in countries with plentiful credit institutions still holds.

Table 11: Reduced form

Dependent variable:	Patents per firm	
	(1)	(2)
Single Market Program Dummy (all high barriers)	0.497	-2.35
	[0.250]**	[1.115]**
Single Market Program Dummy (all high barriers) * No of Credit Institutions per Capita		49.74
		[17.226]***
Constant	-0.332	0.157
	[0.526]	[0.448]
Country fixed effects	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes
Time dummies	Yes	Yes
Observations	270	270

Notes: The sample contains only two years: 1995 and 2002. Observations are country-industry-years. Robust standard errors are in brackets. They are clustered at the country level. ***, **, * indicates statistical significance at 1%, 5% and 10% respectively.

There are concerns with difference-in-difference estimation of this nature where the dependent variable is likely highly persistent that standard errors are underestimated due to serial correlation, as described in Bertrand, Duflo and Mullainathan (2004). Although the time series variation in our sample is small, concerns remain. One technique to ensure that this problem is not responsible for the statistical significance of our results is to throw out the time series variation and estimate a further “reduced form” specification, the results of which are displayed in Table 11. These results take just observations from 1995 and 2002 and use the stronger of our two instruments, the SMP variable.[90] We reduce this variable to a simple step function so that it is equal to one in 2002 in sectors that were most affected by the SMP and equal to zero everywhere else. This step function is interacted with the number of credit institutions per capita. Column (1) shows that country-industries most affected by the SMP increased in patents per firm more so than those country-industries less affected. Column (2) shows our key result, that this positive effect of competition on innovation was greater in countries with numerous credit institutions per capita. This specification also addresses, at least in part, concerns that the main results may have been driven by measurement error in the profitability measure of PMC.

Table 12: Firm level estimation

Dependent variable:	Patent Count					
	(1)	(2)	(3)	(4)	(5)	(6)
1-Profitability	-0.338	0.747	-9.972	-8.111	3.036	5.595
	[0.886]	[3.791]	[4.530]**	[3.377]**	[1.825]*	[2.622]**
1-Profitability * No of Credit Institutions per Capita			171.787	169.424		
			[85.357]**	[83.877]**		
1-Profitability * Deposit Insurance					-3.501	-3.563
					[1.488]**	[1.447]**
Pre-Sample Mean of Patents	0.007	0.007	0.008	0.008	0.008	0.008
	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***
Control Function		-1.069		-1.797		-2.447
		[3.174]		[3.318]		[2.683]
Output Gap	-0.011	-0.001	-0.063	-0.044	-0.036	-0.016
	[0.048]	[0.042]	[0.055]	[0.046]	[0.044]	[0.049]
Constant	1.176	0.478	3.462	2.282	4.753	3.236
	[1.169]	[2.916]	[1.312]***	[1.995]	[1.653]***	[3.062]
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
2 Digit Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3449	3449	3449	3449	3449	3449

Notes: The time period is 1995 to 2002 inclusive. Observations are firm-years. Robust standard errors are in brackets. They are clustered at the industry level. ***, **, * indicates statistical significance at 1%, 5% and 10% respectively. The sample is the number of firm that have at least one observation between 1990 and 1994, for calculation of the pre-sample mean.

[90] We take our two SMP measures here and combine them into one variable so that it represents all sectors with high non-tariff barriers before the program started.

Finally, Table 12 shows that our main results hold when we control for time-invariant firm heterogeneity in patenting. The concern being that firms are inherently different in countries with different financial arrangements and this difference determines how they patent in reaction to changes in market conditions. Where these difference are time-invariant and where they determine previous patenting behavior, they can be controlled for using a pre-sample mean of patents for each firm, as suggested in Blundell, Griffith, and Windmeijer (2002). Pre-sample information is not available for all of the firms in our sample, only 435 out of the 618 in the baseline sample. Nevertheless the results on this smaller sample are consistent with the main results.

5. CONCLUSION

This paper finds evidence of complementarities between product market competition and financial institutions. It uses product market reforms and anti-trust action as exogenous variation in product market competition in manufacturing sectors, in conjunction with proxies for good financial institutions across countries. We found that countries with a larger number of credit institutions per capita and low deposit insurance benefit more through higher innovation rates, from increases in competition. We have also shown that this result is consistent with an application of a model of step-by-step innovation to the case where good financial intermediation alleviates agency costs.

The policy relevance of this work is clear. Many policy reforms in Europe and elsewhere have aimed at increasing product market competition, in an effort to improve economic performance along several dimensions, including productivity. A large body of research has focused on the effects of competition on firms' incentives to increase productivity through innovation and recent work finds strong support of a positive relationship. However, the relationship depends on initial conditions in that the effect is more positive in sectors that are initially technologically advanced and indeed may be negative in sectors that are initially technologically backward. This suggests that other institutions that affect steady state innovation rates may be important determinants of which sectors or economic regions will most likely experience the positive effect of PMC. The results in the current paper suggest that policies that encourage good financial intermediation may increase the positive effect of PMC on innovation.

Much further work is required in this area. It would support these findings greatly if it were observed that a correlation existed between industry measures of distance from technological frontier and the financial institutional variables used herein. Furthermore, any microeconomic evidence that firms in those countries with low numbers of credit institutions or high deposit insurance actually are more financially constrained would greatly support the result.

APPENDIX

Theory

This section shows that the key results can be obtained from both the simple single-sector and the "escape competition" version of the Aghion-Howitt model.

Single sector Aghion-Howitt model, with Financial Intermediation

This section describes the simplest version of the model in Aghion and Howitt (2005). Each discrete time period a final good is produced using a quantity x of an intermediate good of quality A, according to the technology $y = Ax^{\alpha}$. In the intermediate sector L individuals each endowed with one unit of labour can supply this labour to either produce the intermediate good (via a one-for-one technology) or in research to improve the quality of the intermediate good. Specifically an entrepreneur who invests z units of labour innovates with probability λz, discovering an improved intermediate good of quality γA, where $\gamma > 1$. The entrepreneur enjoys monopoly power for one period, during which he is constrained by a competitive fringe that supplies the intermediate good at cost $\chi > 1$ units of labour instead of one. The entrepreneur's profits from successful innovation are thus: $\pi = (\chi - 1)wx$, where w is the wage and x is the amount of labour devoted to production of the intermediate good. The entrepreneur will choose how many labour units, n, to devote to research so that the marginal cost of research equals the expected marginal benefit: the research arbitrage condition $w = \lambda\gamma\pi$. Using the expression for profits, dividing by the wage and using the labour market clearing condition, $x + n = L$, yields the expression for the steady-state amount of research labour:

$$n = L - \frac{1}{\lambda\gamma(\chi - 1)}.$$

This expression determines the steady-state rate of productivity growth. An increase in PMC is a decrease in the cost structure of the competitive fringe; a decrease in χ. This unambiguously decreases the labour resources devoted to research as it decreases the profits from innovation. This is the Schumpeter or "discouragement" effect of PMC on innovation.

King and Levine (1993b) introduce a financial intermediary who can discover the ability of individuals to perform research, ϕ, at cost f labour units. The financial intermediary requires

f/ϕ labour units per successful researcher to break even.[91] This increases the cost of innovation producing a new research arbitrage condition: $(1+f/\phi)w=\lambda\gamma\pi$. After substitution of profits and rearrangement this yields:

$$n = L - \frac{1+f/\phi}{\lambda\gamma(\chi-1)}.$$

More efficient information gathering by financial intermediates reduces *f*, decreasing the cost of innovation and increasing innovation. Also, the negative effect of increased PMC (reduction in χ) on innovation is exacerbated when agency costs are high:

$$\frac{\partial n}{\partial \chi} = \frac{1+f/\phi}{(\lambda\gamma(\chi-1))^2}.\lambda\gamma > 0,$$

$$\frac{\partial^2 n}{\partial \chi \partial f} = \frac{1/\phi}{(\lambda\gamma(\chi-1))^2}.\lambda\gamma > 0.$$

The reduction of the return to innovation from increased PMC decreases the incentive to innovate more when agency costs are high.

Escape Competition, with Financial Intermediation

This section describes the "escape competition" variant of the Aghion-Howitt model, where competition is modeled as an improvement in the cost structure of a competitive fringe that (rather than competition being an increase in the threat of entry as presented in the main text). Again starting with the multi-sector model of step-by-step innovation with a technological frontier that exogenously increases the quality of intermediary goods by a factor γ each period, so that it moves each period from $\overline{A}_{t-1}$ to $\overline{A}_t = \gamma\overline{A}_{t-1}$. Three types of sectors exist, denoted by $j \in \{0,1,2\}$ to produce intermediary goods used in the production of a final good. Each sector contains an incumbent firm that produces the intermediate good at unit cost and a competitive fringe that produces the same good at cost $\chi > 1$. Sector *j* starts each period able to produce a good of quality $\overline{A}_{t-1-j}$. Types 0 and 1 innovate with probabilities μ_0, μ_1 respectively attaining a quality level of $\overline{A}_{t-j}$, type 2 sectors innovate automatically. Therefore sector types 0 and 1 retain their type through innovation and type 2 sectors remain type 2 sectors. With fixed probability ε,

[91] Break even evaluation price, *q*, for a financial intermediary when an individual incapable of research has no value (as a researcher) is given by: $\phi q + (1-\phi)0 = wf$, where *w* is the wage rate.

entry by a technologically advanced foreign firm occurs in type 2 sectors changing them to type 0 sectors.

The cost of innovation is the units of labour devoted to research plus an evaluation cost of f/ϕ for each unit as before. Also the cost of innovation is increasing in its target quality level, $\gamma \overline{A}_{t-1-j}$.

The firm chooses the optimal level of innovation probability by maximizing its expected profits, subject to the cost of innovation:[92]

$$\max_{\mu_{jt}} \left\{ \mu_{jt} \delta_j \overline{A}_{t-j} + \left(1-\mu_{jt}\right) \delta'_j \overline{A}_{t-j-1} - \frac{1}{2} \gamma \overline{A}_{t-j-1} \left(1+f/\phi\right) \mu_{jt}{}^2 \right\}.$$

The solution of this yields the research arbitrage condition for each sector type. Post-innovation, type 0 sectors are unconstrained monopolists, whereas type 1 sectors are still constrained by the competitive fringe with marginal cost χ. The research arbitrage conditions for each sector are:

$$\mu_0 = \frac{1}{\left(1+f/\phi\right)} \left\{ \delta(1/\alpha) - \frac{1}{\gamma} \delta(\chi) \right\}$$

$$\mu_1 = \frac{1}{\left(1+f/\phi\right)} \left\{ 1 - \frac{1}{\gamma} \right\} \delta(\chi).$$

The profit function $\delta(.)$ is strictly increasing in its argument, and $\delta(1/\alpha)$ is the profit of an unconstrained monopolist, $\delta(\chi)$ is the profit of an incumbent constrained by a fringe with cost χ. An increase in PMC is a decrease in the cost of the fringe and, from the expressions above, increases innovation effort in type 0 sectors (the "escape" effect) and decreases innovation in type 1 sectors (the "discouragement" effect). The effect on aggregate innovation in the full economy from an increase in PMC depends on the proportion of type 0 and type 1 sectors. Our interest here is how agency costs change the effect of PMC on innovation.

If we let $\Delta = \delta(\chi)$, the short-term effect of a decrease in PMC (an increase in Δ) on economy wide innovation is given by:

$$\left.\frac{\partial I}{\partial \Delta}\right|_q = q_0 \frac{\partial \mu_0}{\partial \Delta} + q_1 \frac{\partial \mu_1}{\partial \Delta},$$

[92] Profits increase with the quality of the intermediate good. The factor δ adjusts profits for the level of competition from the fringe, and can differ depending on the sector *j* and whether or not the incumbent has innovated, as denoted by δ'.

where q_0 and q_1 are the proportion of type-0 and type-1 sectors respectively. This varies with agency costs as (after evaluating the derivatives in the expression above):

$$\left.\frac{\partial^2 I}{\partial f \partial \Delta}\right|_q = \frac{\partial}{\partial f}\left\{\frac{1}{1+f/\phi}\left[-\frac{q_0}{\gamma}+q_1\left(1-\frac{1}{\gamma}\right)\right]\right\}.$$

If this second derivative is positive it means that high agency costs increases the extent that PMC discourages innovation, or conversely, better financial intermediation increases the positive effect of PMC on innovation. Continuing the differentiation yields:

$$\left.\frac{\partial^2 I}{\partial f \partial \Delta}\right|_q = -\frac{1/\phi}{(1+f/\phi)^2}\left[-\frac{q_0}{\gamma}+q_1\left(1-\frac{1}{\gamma}\right)\right]+\frac{1}{(1+f/\phi)}\left[-\frac{1}{\gamma}\frac{\partial q_0}{\partial f}+\left(1-\frac{1}{\gamma}\right)\frac{\partial q_1}{\partial f}\right]. \tag{A1}$$

If we let the productivity increase from an innovation, γ tend to one the expression simplifies to:

$$\left.\frac{\partial^2 I}{\partial f \partial \Delta}\right|_q = \frac{1/\phi}{(1+f/\phi)^2}q_0+\frac{1}{(1+f/\phi)}\left[-\frac{\partial q_0}{\partial f}\right]. \tag{A2}$$

This expression is positive if the number of frontier sectors is decreasing in agency costs. In the steady state the flow conditions into and out of each of sectors types 0, 1, 2 are:

$$q_2\varepsilon = q_0(1-\mu_0)$$

$$q_0(1-\mu_0) = q_1(1-\mu_1)$$

$$q_1(1-\mu_1) = q_2\varepsilon$$

$$q_0+q_1+q_2 = 1$$

It is not immediately obvious that an increase in agency costs decreases the proportion of type-0 sectors, as a decrease in innovation effort in both type-0 and type-1 sectors increases the number of type-2 sectors which increases the number that spontaneously become type-0 sectors through foreign entry, $q_2\varepsilon$. We can, however, show that q_0 does decrease in *f* as follows. From the flow conditions:

$$q_0 = \left[1+\frac{(1-\mu_0)}{(1-\mu_1)}+\frac{(1-\mu_0)}{\varepsilon}\right]^{-1} \tag{A3}$$

$$\frac{\partial q_0}{\partial f} = -\left[1 + \frac{(1-\mu_0)}{(1-\mu_1)} + \frac{(1-\mu_0)}{\varepsilon}\right]^{-2}\left[\frac{\partial}{\partial f}\frac{1-\mu_0}{1-\mu_1} - \frac{1}{\varepsilon}\frac{\partial \mu_0}{\partial f}\right] \tag{A4}$$

The first bracket must be positive, the second term in the second square bracket is positive from the definition of μ_0 above. Therefore, $\frac{\partial q_0}{\partial f} < 0$ if:

$$\frac{\partial}{\partial f}\frac{1-\mu_0}{1-\mu_1} = \frac{\frac{1-\mu_0}{1-\mu_1}\frac{\partial \mu_1}{\partial f} - \frac{\partial \mu_0}{\partial f}}{1-\mu_1} > 0\,. \tag{A5}$$

This is true because, from the definitions of μ_0 and μ_1: $\frac{1-\mu_0}{1-\mu_1} < 1$, $\left|\frac{\partial \mu_0}{\partial f}\right| > \left|\frac{\partial \mu_1}{\partial f}\right|$ and both derivatives are negative. These properties are consequences of the fact that there are greater incentives to innovate in frontier sectors than in laggard sectors, and therefore $\mu_0 > \mu_1$.

To recap: for small productivity gains, agency costs decrease the positive effect of PMC, due partly to the dampening of the positive reaction of innovation to competition in frontier sectors (1st term in A2) and due partly to the decrease of the proportion of frontier sectors in the economy (2nd term in A2).

If we relax the small γ assumption, it is still likely that A2 is positive. Given that $\frac{q_1}{q_0} = \frac{1-\mu_0}{1-\mu_1}$ from the flow conditions, we can re-write the contents of the first term in A1 as: $-\frac{1/\phi}{(1+f/\phi)^2}\left[\frac{q_0}{\gamma}\left(-1+\frac{1-\mu_0}{1-\mu_1}(\gamma-1)\right)\right]$. Letting $\frac{1-\mu_0}{1-\mu_1} = 1$ (in fact it will always be less than one), this expression will only be negative if $\gamma > 2$, which is unrealistically high.

The second term in A1 could be overall negative if $\frac{\partial q_1}{\partial f}$ is negative and large in magnitude (meaning that the net effect of high agency costs decreases the proportion of laggard sectors, which is possible if the flow into type-1 sectors from type-0 sectors that innovate less is outweighed by the flow into type-2 sectors from less innovation in type-1 sectors). From the flow conditions we can write:

$$q_1 = \left[1 + \frac{(1-\mu_1)}{(1-\mu_0)} + \frac{(1-\mu_1)}{\varepsilon}\right]^{-1} \tag{A6}$$

$$\frac{\partial q_1}{\partial f} = -\left[1+\frac{(1-\mu_1)}{(1-\mu_0)}+\frac{(1-\mu_1)}{\varepsilon}\right]^{-2}\left[\frac{\partial}{\partial f}\frac{1-\mu_1}{1-\mu_0}-\frac{1}{\varepsilon}\frac{\partial \mu_1}{\partial f}\right]. \qquad \text{(A7)}$$

From A5 it is clear that $\frac{\partial}{\partial f}\frac{1-\mu_1}{1-\mu_0}<0$ and, therefore, the only negative term in the second bracket of A6 comes from the $\frac{1}{\varepsilon}\frac{\partial \mu_1}{\partial f}$ term above. We can see that the contribution of this term to the second bracket of A1 is lower in magnitude than a term of opposite sign that is present in via the $\frac{\partial q_0}{\partial f}$ in A1. This is now sufficient to say that A1 is positive. Using A4, A7 and the expression for A1 this is true if:

$$\left|\left(1-\frac{1}{\gamma}\right)\left(1+\frac{(1-\mu_1)}{(1-\mu_0)}+\frac{(1-\mu_1)}{\varepsilon}\right)^{-2}\left(\frac{1}{\varepsilon}\frac{\partial \mu_1}{\partial f}\right)\right| < \left|\left(\frac{1}{\gamma}\right)\left(1+\frac{(1-\mu_0)}{(1-\mu_1)}+\frac{(1-\mu_0)}{\varepsilon}\right)^{-2}\left(\frac{1}{\varepsilon}\frac{\partial \mu_0}{\partial f}\right)\right|$$

Again using $\frac{1-\mu_0}{1-\mu_1}<1$ and $\left|\frac{\partial \mu_0}{\partial f}\right| > \left|\frac{\partial \mu_1}{\partial f}\right|$ this must be true for reasonable values of γ (i.e. <2).

It is interesting to note that the characteristic of the model that drives these properties is that the return to innovation is much larger in frontier (type-0) sectors, therefore innovation effort is greater in these sectors in the steady state and reacts more elastically to changes in the cost of innovation effort.

Table A.1: Descriptive Statistics and Variable Definitions

Variable	Description and source	Mean (s.d.)
Competition	$1-\dfrac{ValueAdded_{ijt}-LabourCosts_{ijt}}{ValueAdded_{ijt}}$	0.6532 (0.1395)
Competition (including capital)	$1-\dfrac{ValueAdded_{ijt}-LabourCosts_{ijt}-CapitalCosts_{ijt}}{ValueAdded_{ijt}}$	0.8845 (0.4229)
Value added	Value added at basic prices plus taxes, less subsidies on production, excluding imports and VAT. At factor costs for Canada and producer's prices for USA; OECD STAN database.	9400.532 (10522.66)
Labour costs	Wages and salaries plus supplements, such as contributions to social security, private pensions, health insurance, life insurance. OECD STAN database	6156.319 (7409.27)
Cost of capital	Yield on USA Government composite bond (10 Years), minus inflation rate, plus assumed depreciation of 7%. OECD Main Economic Indicators for bond yields and consumer price index.	
Capital stock	Calculated using the perpetual inventory method. Depreciation rates are calibrated so that the stocks are similar to the OECD estimates when both are available. OECD STAN database.	
Output gap	Percentage deviation of output from trend; OECD Economic Outlook.	-0.5598 (1.9456)
Number of Credit Institutions	CESifo DICE (European Commission)	0.04 (0.03)
Deposit Insurance	Ratio of deposit coverage limit to GDP per capita. CESifo DICE (World Bank).	1.94 (1.74)

Table A.2: Firm Characteristics

Country	Average Total Assets ($th)	Average Total Sales ($th)
Belgium	7,254,373	1,898,202
Denmark	1,362,743	178,704
Finland	2,901,841	1,444,286
France	12,113,114	729,519
Germany	45,733,020	5,288,165
Italy	8,263,993	186,011
Netherlands	22,891,864	5,239,465
Norway	921,654	144,163
Spain	4,640,659	1,121,886
Sweden	5,211,173	808,736
United Kingdom	44,860,443	1,872,350

Notes: Averages are taken for the year 2000 and are characteristics of the listed parent firm.

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CHAPTER 4 | EMPLOYMENT PROTECTION LEGISLATION, MULTINATIONAL ENTERPRISES AND INNOVATION

Rachel Griffith and Gareth Macartney

Abstract

The theoretical effects of labour regulations such as employment protection legislation (EPL) on innovation is ambiguous, and empirical evidence is thus far inconclusive. EPL increases job security and the greater enforceability of job contracts may increase worker investment in innovative activity. On the other hand EPL increases adjustment costs faced by firms, and this may lead to under-investment in activities that are uncertain including innovation and other technologically advanced activities. In this paper we find empirical evidence that multinational enterprises locate more innovative activity in countries with high EPL, however they locate technologically advanced innovation in subsidiaries located in countries with low EPL.

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1. INTRODUCTION

Labour market regulations have been a focus of policy concern in the European Union. There is now considerable evidence that rigid labour markets are associated with higher unemployment.[93] More recently attention has focused on the impact of labour regulations on the incentive to invest in productivity enhancing innovation and growth. Here the relationship is much less clear. When making its innovation decision a firm considers two effects of employment protection legislation (EPL). First, EPL introduces a firing cost to any adjustment to employment made by the firm. Second, this adjustment cost increases job security for existing workers as it reduces the probability of being fired in response to small fluctuations in demand. Efficiency wage arguments suggest that this increases the value of employment for the worker and increases their (unobservable) effort, which in turn can increase the return to innovation for the firm.[94] On the other hand where innovation is radically new and requires new skills, and thus a drastic adjustment to employment, EPL may prohibitively increase the cost of such innovation. Existing models of radical innovation suggest that countries with low EPL have a comparative advantage in radical innovation and experimentation (Saint-Paul 1997, 2002, Samaniego 2006, Bartelsman et al. 2008).[95]

There is a small empirical literature on the relationship between labour regulations and productivity and innovation, however cross-country evidence remains inconclusive, with studies finding divergent results.[96] Such studies struggle to deal with two key

[93] See Nickell (2005), Blanchard and Wolfers (2000), Lazear (1990) and Chapter 2 of this thesis.

[94] See Shapiro and Stiglitz (1984) for the efficiency wage set-up and Boeri and Jimeno (2005) for an application to EPL. Although not its central point, workers invest more in general training in the presence of search frictions in the labour market when they are less likely to be fired by their present employer in Acemoglu (1997). See also Akerloff (1982), Agell (1999) and Chapter 10 of Saint-Paul (1996) for the positive effects of EPL.

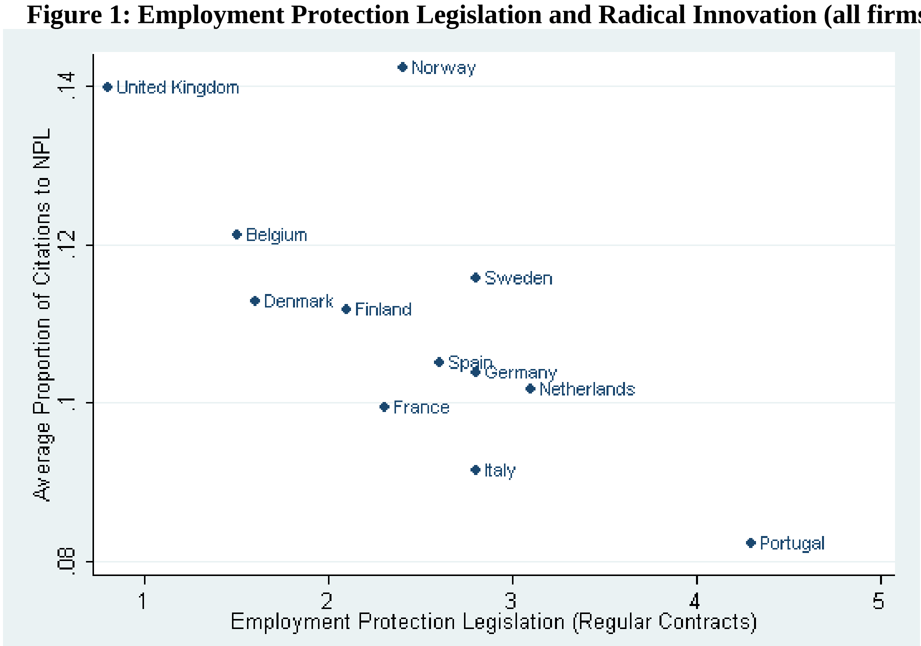
[95] Also Cunat and Melitz (2007) provide theoretical and empirical evidence that countries with flexible labour markets have a comparative advantage in industries with high demand volatility. Caballero et al. (2004) provide theoretical and empirical evidence that countries with strong EPL are slow to adjust employment, and that this is associated with low productivity growth.

[96] Storm and Nastepaad (2007) find high EPL is associated with greater productivity growth. Bassanini et al. (2001) find that EPL has a negative effect in less coordinated countries, in higher coordinated countries workers and firms can align their interests better. Similarly, Scarpetta and Tressel (2004) find a significant impact of EPL on multi-factor productivity growth when interacted with bargaining coordination, but no linear result. Hall and Soskice (2001) argue that differences in specialisation between Germany and the US are due to the more market orientated financial and labour market institutions in the US. Bartelsman et al. (2008) find that EPL decreases productivity in technologically advanced sectors. See also Akkermans et al. (2005).

identification problems. One is that the effect of EPL may depend on the *nature* of innovation, and in most data it is difficult to distinguish between incremental and radical innovation. Two is that in the cross-section labour regulations may be correlated with unobservable characteristics of countries, industries and firms that determine innovation. We deal with the first challenge by using an intuitively appealing measure of radical innovation: the proportion of citations on a patent application made to scientific journals, referred to as non-patent literature (NPL). We tackle the second challenge by basing our results on an identification strategy that uses variation within multi-national enterprises (MNEs) from 15 different countries, and therefore controls for unobservable characteristics of the home country, industry and firm that affect the innovation decision. We find that MNEs perform more overall innovation in high EPL countries, but that the same MNEs perform more radical innovation in low EPL countries.

This latter result can be seen in Figure 1, where we use aggregate data and show the average proportion of citations to NPL made by all private sector firms in our data.[97] The downward sloping relationship suggests that there is less radical innovation performed in countries with high EPL.

Figure 1: Employment Protection Legislation and Radical Innovation (all firms)



Notes: Averages are calculated at the three digit industry level using all private sector firms for the years 1997-2003. The y variable is the country average across these industries.

[97] This is a very large sample of both listed and unlisted subsidiary level firms, see Macartney (2008).

If we focus on MNEs[98] we see statistically significant evidence of both a positive effect of EPL on overall innovation, Figure 2, and a negative effect of EPL on radical innovation, Figure 3.[99]

Figure 2: Employment Protection Legislation and Innovation (MNEs)

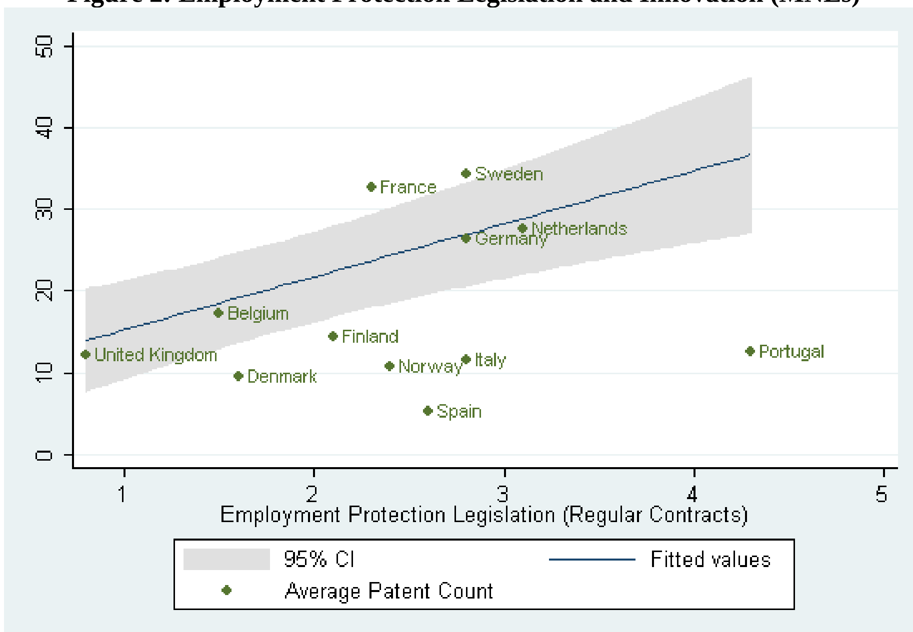
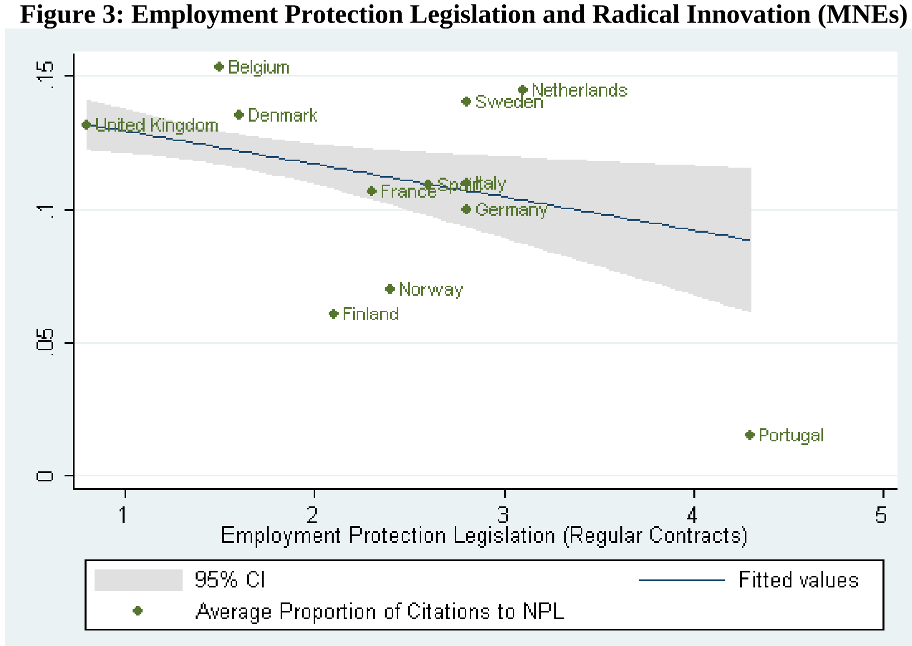


Figure 3: Employment Protection Legislation and Radical Innovation (MNEs)



[98] This is a sample of 1,378 subsidiaries of MNEs, see Section 4 for details of the data used.

[99] In Figures 2 and 3 the fitted line is weighted by the number of subsidiaries. The confidence interval uses standard errors clustered at the country level.

We show that these results are robust to controlling for firm fixed effects and for an extensive set of country level regulatory and factor endowment characteristics.

The main contribution of this paper is empirical. In addition we describe a model that incorporates both positive and negative effects of EPL on innovation incentives for firms.[100] We distinguish between incremental innovation and radical innovation (RI): RI is potentially more profitable than incremental innovation but requires a large and drastic employment adjustment as workers with new skills are required to implement it (as in Chapter 8 of Aghion-Howitt 1998). EPL increases this cost of adjustment, but it also has positive effects on both types of innovation by increasing workers' effort to further increase the productivity of innovations. The model suggest that, for plausible parameter values, the optimal level of investment in radical innovation decreases with EPL but that the optimal level of investment in incremental innovation increases with EPL.

The paper is related to several literatures. It is directly related to the growing literature on the effects of labour market regulations on productivity and by extension to the papers on cross-country patterns of specialization and national institutions.[101] There is a related literature on the product life-cycle that distinguishes between different new product innovation and mature product innovation, where demand is more certain for the latter.[102] It also relates to the endogenous growth literature and the model presented builds heavily on the framework of Aghion-Howitt, where the distinction between radical and incremental innovation is through the employment adjustment required for radical innovation.[103] Our paper is also related to the literature on the location of activity by MNEs.[104]

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[100] To our knowledge models of innovation have tended to emphasise the negative effect of EPL on radical innovation and then explained country specialisation using comparative advantage.

[101] Nunn (2007), Carlin and (2003).

[102] Klepper (1996) and Breschi et al. (2000), Audretsch (1995), Puga and Trefler (2005), and Saint-Paul (1997, 2002).

[103] As opposed to the distinction that radical innovation is less likely to succeed than incremental innovation, as in Saint-Paul (1997, 2002) and Bartelsman et al. (2008), we argue that this was appropriate for our sample of large incumbent firms, whereas models of risky innovation and high firing costs in the event of failure seemed more appropriate for small firms and entry and exit.

[104] Ekholm and Hakkala (2007), Devereux and Griffith (1998). Haaland & Wooton (2003) show that multi-national enterprises will locate high risk projects in countries with low redundancy costs in the presence of industry or economy wide wage bargaining, and when the risk profile of the MNE is different to that of domestic firms.

This paper proceeds as follows: section 2 describes a simple model of incremental and radical innovation; section 3 describes our identification strategy; section 4 describes our empirical specification and data, explaining our measure of radical innovation; section 5 describes our key results; a final section concludes.

2. THEORETICAL BACKGROUND

The current literature on the ambiguous effect of EPL on productivity suggests that the nature of innovation has a role to play. The model in this section is driven in part by the difference between radical innovation and incremental innovation emphasized by the endogenous growth literature (see Aghion-Howitt 1998). Where successful, radical innovation requires a drastic adjustment of employment as the human capital of existing workers is rendered obsolete. EPL increases this cost by way of firing costs. In this model radical innovation is more valuable than incremental innovation and more costly.[105] With a small uncertainty in future demand EPL also has a positive effect on the returns to both types of innovation, in that it increases worker commitment and their efforts in making the new technology more productive through learning by doing. The model predicts that EPL will increase incremental innovation effort, but at sufficiently high levels it will decrease radical innovation effort. The firm will more likely choose to perform radical innovation in low EPL regimes and incremental innovation in high EPL regimes, which is this central prediction tested in this paper.

2.1. General Framework

The basics of this model are similar to Aghion-Howitt (1998). Innovation improves the productivity of intermediate goods supplied by a firm for use in the production of a final good. A further improvement on this productivity gain comes via the effort (or learning by doing) of production workers. This effort is higher in the presence of employment protection legislation (EPL), which takes the form of higher firing costs per worker, φ, as the firm can credibly commit to sharing some of the surplus with workers.

We distinguish between two types of innovation: radical innovation and incremental innovation. Radical innovation is potentially higher productive, but makes existing

[105] Although it is not more risky as in Saint-Paul (1997, 2002) and the model in Bartelsman et al. (2008). If it where and the cost of failure (exit) increased with EPL then this would enhance our predictions.

human (or physical) capital obsolete. We model this as requiring all production workers to be replaced by more highly skilled workers, at firing cost φ per worker. Incremental innovation increases productivity, but to a lesser extent, and existing workers can still be used. EPL's effect on worker effort will have an increasing effect on the returns to both types of innovation, but due to the firing costs it will also have a negative effect on radical innovation.

Our main interest is in the impact of EPL on innovation incentives. The main impact of EPL is on costs, and therefore to focus on this effect we assume away any strategic considerations in the product market. A final good is produced using a continuum of intermediate goods produced by firms, each one of which is a monopolist in its market, using the technology,

$$y = \int_0^1 (Z(e_i)A_i)^{1-\alpha} x_i^{\alpha} di \quad .$$

Profits of the intermediate firm are given by,

$$\pi_i = \delta Z(e_i)A_i \quad ,$$

where *i*: indexes firms and industries (since each firm is a monopolist in its industry).

We consider the following timing of events:

Intermediate producers draw an initial productivity level A_i^0. Firms decides whether to invest in radical or incremental innovation, and how much to invest (which determines the probability of success μ_i^R, μ_i^I). If successful, incremental innovation leads to a productivity increase of $\gamma > 1$ and, if radical innovation is successful productivity increases by a factor of γ^2. Innovation incurs a fixed cost.

Productivity is enhanced by the efforts of workers. However, in the case of radical innovation existing workers do not have the required skills to work with the new technology and must be fired and replaced by more skilled workers. Production workers decide the level of investment in unobservable effort e_i^j, which increases productivity by a factor $Z(e)$. A demand shock occurs which leads to the possibility of the worker being fired. We assume that the future uncertainty in demand is small enough to be trivial to the firm, although of importance to the workers.[106]

Intermediate production occurs, if the firm chooses incremental innovation then it uses existing workers. If the firm chooses radical innovation then existing production workers are fired at cost φ per worker. They are replaced at zero hiring costs by more skilled production workers. Output is sold and surplus shared between the firm and its workers. We are interested in the innovation incentives for the intermediate producers.

Note the key notations are : *i*: firms; *j= 0, I, R*: innovation type; φ: firing costs per worker; $\gamma > 1$: productivity gain from incremental innovation (if successful); γ^2: productivity gain from radical innovation (if successful); δ: competition in intermediate goods market; $s(\varphi)$: probability that a worker is fired after incurring effort; β: worker bargaining power; A_i^0: intermediate producers initial productivity level; F^I, F^R: fixed costs of innovation; e_i^j: worker effort, enhances firm specific productivity; μ_i^I, μ_i^R: the level of innovation effort, and the probability of success; c_i^I, c_i^R: variable costs of incremental and radical innovation; f_i: firing cost incurred if radical innovation is successful; π_i^j: profits for each *j* technology; and V_i^j: surplus for each *j* technology.

Working backwards:

Output generates surplus for the firm. These are given by,

$$V_i^0 = (1-\beta)\pi_i^0 \tag{1}$$

$$V_i^I = \mu^I(1-\beta)\pi_i^I + (1-\mu^I)(1-\beta)\pi_i^0 - c_i^I - F^I \tag{2}$$

$$V_i^R = \left(\mu^R(1-\beta)\pi_i^R - f_i\right) + (1-\mu^R)(1-\beta)\pi_i^0 - c_i^R - F^R \tag{3}$$

where

[106] The implication is that innovation and production are co-located. Therefore the effect EPL has on worker incentives affects the firm's innovation incentives. Such a co-location is more likely when technology transfer costs are high relative to product transport costs (see Ekholm and Hakkala 2007). This is consistent with a model where location is endogenous and determined by the effect EPL has on the benefits to innovation. That is, if transport costs are low so that production can be located anywhere, firms may choose to locate innovation and production in countries where the labour market environment is conducive to their intended type of innovation. While over 60% of R&D costs are labour costs, it seems unlikely that very highly skilled researchers require job security regulation for motivation.

$$c_i^j = \frac{1}{2} A_i^j \left(\mu_i^j\right)^2 . \tag{4}$$

Intermediate production occurs. Output of the intermediate firm is given by

$$\pi_i^j = \delta Z\left(e_i^j\right) A_i^j , \tag{5}$$

where δ reflects the shape of the residual demand curve the firm faces.

If the firm has chosen not to innovate or chosen incremental innovation then it uses existing workers. If the firm chose radical innovation then existing production workers do not have the skills to work with the new technology and are fired by the firm. EPL is modeled as a firing cost of φ per worker (a bureaucratic cost, not a transfer to the worker), that makes employment adjustment costly.[107] New workers are hired at zero hiring costs. These firing costs take the form

$$f_i = \varphi k Z\left(e_i^0\right) A_i^0 \tag{6}$$

where the term $kZ\left(e_i^0\right)A_i^j$ is the number of existing workers employed by the firm.

Demand shock occurs. There is a shock to demand that means that the worker may be fired with probability $s(\varphi)$. This occurs after the worker has committed to an effort level. We assume that the future uncertainty in demand is small enough to be trivial to the firm, although of importance to the workers (see Acemoglu 1997, and Boeri and Jimeno 2005). The firing cost of φ per worker makes employment adjustment in the face of demand shocks unprofitable to the firm and, therefore, $s = s(\varphi), s'(\varphi) < 0$. In this way EPL increases workers' job security and therefore their effort. Specifically, we can show that if there is a probability *p* of a drop in demand from θ^h to θ^l then (see Appendix A):

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[107] There are conditions where EPL is irrelevant to firm location, specifically when EPL takes the form of a redundancy payment rather than a bureaucratic cost to the firm. Pissarides (2001) and Lazear (1990) find that with endogenously determined wages, expected redundancy costs are fully reflected in the wage. The worker takes into account both the probability of firm bankruptcy and the size of the redundancy payment when bargaining over wages. We have assumed this situation away by interpreting EPL as a regulation that results only in a (bureaucratic) firing cost to the firm and not a transfer to the worker. However, EPL as redundancy will affect location decisions if wage bargaining is conducted at the industry level rather than at the firm level and the probability of bankruptcy is private information to the firm and is different to the industry average (Haaland and Wooton 2003). The worker accepts a low (high) wage if the industry average riskiness is high (low). Therefore a firm that is more risky than the average is worse off, as it still has to pay the same wage as other firms but has a higher probability of paying a redundancy payment. Therefore risky firms (or firms more likely to make employment adjustments) have an incentive to locate their activities in a low EPL country.

$$s(\varphi) = p.\left(1 - \left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} (1-\varphi)^{\frac{1}{\alpha-1}}\right). \tag{7}$$

This function is decreasing in φ at an increasing rate: $s'(\varphi) < 0, s''(\varphi) < 0$. Specifying this functional form for $s(\varphi)$ is not necessary for the qualitative predictions of our model, but it will help in discussing the dominant effect of EPL on radical innovation effort for realistic values of φ. For most of the discussion we will continue to use the general function, $s(\varphi)$.

Production workers decide level of effort. This is an investment in unobservable effort, which increases productivity by a factor $Z(e)$ (where $Z(0) = 1, Z'(e) > 0, Z''(e) < 0$). Workers will choose effort to maximise their expected return (dropping $s(\varphi)$'s argument),

$$\max_e \left[(1-s)\beta\pi_i^j + s \cdot 0 - e\right] \tag{8}$$

and substituting equation (5) into (8) we get the following first order condition:

$$Z'\left(e_i^j\right) = \frac{1}{(1-s)\beta\delta A_i^j} \quad . \tag{9}$$

We assume a functional form for Z that displays diminishing returns to workers effort and that is equal to one if workers make zero effort,

$$Z(e) = \sqrt{e+1}\,. \tag{10}$$

Using this we can find optimal worker effort:

$$Z\left(e_i^{j*}\right) = \sqrt{e^* + 1} = \frac{(1-s)\beta\delta}{2} A_i^j\,. \tag{11}$$

Effort is increasing in the initial productivity draw, and increasing in EPL,

$$\frac{\partial Z\left(e_i^{j*}\right)}{\partial\varphi} = -\frac{\partial s}{\partial\varphi}\frac{1}{2}\beta\delta A_i^j > 0\,, \tag{12}$$

since $s'(\varphi) < 0$.

We have assumed that the workers' return to learning-by-doing effort is entirely tied to the firm, i.e. their efforts enhance the productivity of the firm's capital but does not enhance their own productivity. It is important to discuss at this stage what would be the effect of weakening such an assumption. Say the worker gained from their efforts by way of acquiring general skills. Becker (1964) predicts an under-investment in general skills as workers are credit constrained and firms are reluctant to fund skills that the worker may use elsewhere. As described by Acemoglu (1997) it is likely that a contract could be written to mitigate such a problem (penalties for workers who train and quit) and, for our purposes, it is not initially clear what role EPL has to play: EPL will not stop workers leaving once trained and offered a job elsewhere. Acemoglu (1997) considers a model of training and innovation with job market search frictions, where workers can exogenously lose their job with probability s.[108] Costly job search means that when a worker and firm are matched they bargain over the surplus of the match, and therefore over any increased productivity that the worker has achieved through learning-by-doing effort. This leads to an under-investment in training by workers, as there is a probability of being fired and then, after search, receiving only a partial return to their training efforts. Where EPL reduces this probability of being fired, it will mitigate this problem of under-investment, which would be qualitatively consistent with our model.

We have also assumed that the worker's effort is unobservable, otherwise the firm and worker could write a contract specifying e in return for a guaranteed wage in each period. We could relax this assumption and assume that such a contract can be written and that there is a monitoring technology available to the firm so that a worker can be caught shirking with probability q. The efficiency wage paid to the worker so that they do not shirk is increasing in the exogenous probability of spontaneous dismissal in the future ("economic dismissal"), increasing in the exogenous probability of once dismissed getting another job ("flow into employment") and decreasing in the probability of getting caught shirking and subsequently being dismissed ("disciplinary dismissal"), see Shapiro & Stiglitz (1984). EPL can then have two effects: it will decrease the probability of economic dismissal as we have discussed in the previous paragraph, but it will also decrease the probability of disciplinary dismissal. Boeri and Jimeno (2005), argue that for big firms (which is the sample for the current paper), where monitoring is very difficult, the dominant effect of EPL is that it decreases the probability of economic dismissal and therefore increases the value of employment to the worker and reduces the efficiency

[108] Our equation 9 is inspired by equation (2) in Acemoglu (1997).

wage that the firm must pay them. As this lower wage will increase the return to the firm from innovation this will increase the firm's innovative effort, as in our model.

Firm decides level of innovation. The problem facing the firm is to choose the optimal level of innovation effort conditional on type and on worker effort. For incremental innovation, we substitute equation (5) into (2) to get,

$$\max_{\mu_i^I}\left[\mu^I(1-\beta)\delta Z\left(e_i^{I*}\right)A_i^I+\left(1-\mu^I\right)(1-\beta)\delta Z\left(e_i^{0*}\right)A_i^0-c_i^I-F^I\right], \qquad (13)$$

and substituting in equation (4) and using the fact that $A_i^I=\gamma A_i^0$ we get the firm's first order condition. The optimal innovation efforts are given by the first order condition, noting that $Z\left(e_i^{I*}\right)=\gamma Z\left(e_i^{0*}\right)$:

$$(1-\beta)\left(\delta Z\left(e_i^{0*}\right)\gamma^2A_i^0-\delta Z\left(e_i^{0*}\right)A_i^0\right)-\gamma A_i^0\mu_i^{I*}=0, \qquad (14)$$

which implies that firm innovation effort will be:

$$\mu^{I*}=(1-\beta)\left(\gamma-\frac{1}{\gamma}\right)\delta Z\left(e_i^{0*}\right). \qquad (15)$$

This is increasing in EPL as $s'(\varphi)<0$.

With radical innovation we substitute equations (4), (5), (6) into (3) and using the fact that $A_i^R=\gamma^2A_i^0$ we get:

$$\max_{\mu_i^R}\mu_i^R\left[(1-\beta)\delta Z\left(e_i^{R*}\right)\gamma^2A_i^0-\varphi kZ\left(e_i^{0*}\right)A_i^0\right]+\left(1-\mu_i^R\right)(1-\beta)\delta Z\left(e_i^{0*}\right)A_i^0-\frac{1}{2}\gamma^2A_i^0\left(\mu_i^R\right)^2-F^{RI}. \qquad (16)$$

The optimal innovation effort is given by the first order condition:

$$(1-\beta)\left(\delta Z\left(e_i^{0*}\right)\gamma^4A_i^0-\delta Z\left(e_i^{0*}\right)A_i^0\right)-\varphi kZ\left(e_i^{0*}\right)A_i^0-\gamma^2A_i^0\mu^{R*}=0, \qquad (17)$$

which implies that firm innovation effort will be

$$\mu_i^{R*}=\left[(1-\beta)\left(\delta\gamma^2-\frac{\delta}{\gamma^2}\right)-\frac{\varphi k}{\gamma^2}\right]Z\left(e_i^{0*}\right). \qquad (18)$$

Innovation incentives are increasing in workers learning-by-doing effort and therefore EPL has an increasing effect in both cases. Due to the large employment adjustment required in the case of radical innovation, firing costs also have a decreasing effect on the incentives for radical innovation. Using a Taylor approximation for equation (7), see Appendix, we note that the expression for radical innovation is quadratic in firing costs with a maximum turning point, so that radical innovation effort initially increases with φ and then decreases with φ.

These effects can be seen by differentiating with respect to firing costs:

$$\frac{\partial \mu_i^{I*}}{\partial \varphi} = (1-\beta)\left(\gamma - \frac{1}{\gamma}\right)\delta \frac{\partial Z\left(e_i^{0*}\right)}{\partial \varphi}, \tag{19}$$

$$\frac{\partial \mu_i^{R*}}{\partial \varphi} = (1-\beta)\left(\gamma^2 - \frac{1}{\gamma^2}\right)\delta \frac{\partial Z\left(e_i^{0*}\right)}{\partial \varphi} - \frac{\varphi k}{\gamma^2}\frac{\partial Z\left(e_i^{0*}\right)}{\partial \varphi} - \frac{k}{\gamma^2} Z\left(e_i^{0*}\right). \tag{20}$$

It is useful at this stage to use a specific functional form for *Z(.)*. For small φ we can write (see equation A9):

$$s(\varphi) = p.\left(1 - \left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}}\right) - p.\frac{1}{(1-\alpha)}\left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}}\varphi. \tag{21}$$

Inserting this into equation (11) and letting $b = \frac{1}{(1-\alpha)}\left(\theta^h/\theta^l\right)^{\frac{1}{\alpha-1}}$ we can write:[109]

$$Z(\varphi, A) = \frac{1}{2}\left(1 - p\left(1 - (1-\alpha)b - b\varphi\right)\right)\beta\delta A = \frac{1}{2}\left(\left(1 - p + p(1-\alpha)b\right) + pb\varphi\right)\beta\delta A. \tag{22}$$

Equations (19) and (20) now become:

$$\frac{\partial \mu_i^{I*}}{\partial \varphi} = (1-\beta)\left(\gamma - \frac{1}{\gamma}\right)\delta \frac{1}{2} pb\beta\delta A \tag{23}$$

$$\frac{\partial \mu_i^{R*}}{\partial \varphi} = (1-\beta)\left(\gamma^2 - \frac{1}{\gamma^2}\right)\delta \frac{1}{2} pb\beta\delta A - \frac{\varphi k}{\gamma^2}\frac{1}{2} pb\beta\delta A - \frac{k}{\gamma^2}\frac{1}{2}\left(\left(1 - p + p(1-\alpha)b\right) + pb\varphi\right)\beta\delta A \tag{24}$$

Equation (23) is strictly positive as expected. Considering equation (24), the first term must be positive for $\gamma > 1$ and the second two terms are negative and increasingly so in φ. To find the point at which firing costs start to have a negative effect on radical innovation, $\hat{\varphi}^R$, set this expression equal to zero and solve:[110]

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[109] Note that *b* is decreasing in the severity of the shock. Its range is between zero and $\frac{1}{1-\alpha}$.

[110] Using $\frac{\delta}{k} = \left(\frac{1}{\alpha} - 1\right)$.

$$2\hat{\varphi}^R = \frac{1}{kpb}\left[(1-\beta)(\gamma^4 - 1)\delta pb - k(1-p+p(1-\alpha)b)\right] \quad (25)$$

$$2\hat{\varphi}^R = (1-\beta)(\gamma^4 - 1)\left(\frac{1}{\alpha} - 1\right) - \frac{(1-p)}{pb} - (1-\alpha)\,. \quad (26)$$

Therefore, $\hat{\varphi}^R$ is lower when the productivity gains from innovation are low (low γ); the monopoly price for the intermediate good is low (low $1/\alpha$)[111]; and the firms gets a low proportion of the return to innovation (worker bargaining power, β, is high). Also, $\hat{\varphi}^R$ is lower when the extent to which φ increases learning by doing is lower: when the probability of a negative demand shock, *p*, is low and therefore the relevance of EPL in making workers feel secure in their jobs is lower; when the elasticity of final good output with respect to intermediate good input is low ($-(1-\alpha)$ is low) as this reduces the intermediate good adjustment required in the face of a small demand shock and therefore the possibility of getting fired and, again, the relevance of EPL to job security (see Appendix).

How does $\hat{\varphi}^R$ compare with realistic values for firing costs? We can show quite easily that for reasonable values of the parameters in our model $\hat{\varphi}^R$ is outside the likely range of φ. The firing cost φ is likely to be a proportion of the worker reservation wage which is normalized at one, and therefore it is realistic to assume that φ is between zero and one. Setting $\alpha = 1/2, b = 2, p = 0.1, \beta = 1/2$ we can calculate that $\hat{\varphi}^R < 0$ for $\gamma \leq 1.821$ and that for $1.821 < \gamma \leq 1.968$, $0 < \hat{\varphi}^R < 1$.[112] In this second range of γ values, EPL increases the value of radical innovation initially, but will start to decrease it again as the radical firing cost effect starts to outweigh the learning by doing effect. Remembering that in this model the productivity gain from an incremental innovation is γ and that for radical innovation is γ^2, the values mentioned here are very large: $\gamma = 1.821$ corresponds to a productivity gain from incremental innovation of 82.1 percent and from radical

[111] α is the elasticity of demand for the intermediate good.

[112] By inserting values into the following expression and solving for γ: $(\gamma^4 - 1) = \frac{1}{(1-\beta)}\left[\left(\frac{1}{\alpha} - 1\right) + \frac{(1-p)}{pb} + (1-\alpha) + 2\hat{\varphi}^{RI}\right]$.

innovation of 231.6 percent. Therefore it is likely that in this model that firing costs have a strictly decreasing effect on radical innovation incentives.

3. EMPIRICAL STRATEGY

In order to investigate the idea that EPL affects the level and type of innovate activity undertaken we consider the decision of MNEs over where to located innovative activities across twelve OECD countries. As emphasised above, our identification strategy is to use variation *within* multi-national enterprises (MNEs) from 15 different countries, which allows us to control for a large range of potentially unobservable characteristics at the firm, industry and home country level. We consider both the total amount of innovative activity, and the most technologically new projects, which we interpret as being those most associated with employment adjustment and volatility (we show evidence to support this interpretation).

Our main measure of the level of innovative activity is a count of patents. We follow the literature (Hausman et al (1984), Pakes (1986), Blundell et al (1999)) and model the count of patents with a linear exponential model.

Consider a multinational firm (*m*), with a number of subsidiaries (*s*) each of which operates in (potentially different) industry (*i*) and is located in country (*c*). We model the level of inventive activity measured by patent applications (*P*) in each location as a function of EPL, a range of other covariates (X), multinational effects (η) and an idiosyncratic error (*u*):

$$P_{ms} = \exp\left(\beta EPL_c + X_{ci} + \eta_m + u_{ms}\right). \qquad (27)$$

Our main interest is in the sign and magnitude of β, recall that the theoretical literature discussed above is ambiguous about what we expect the sign to be - a positive sign would suggest that the dominant effect of EPL is to increases both firms investment in workers and worker commitment, while a negative sign would support the idea that higher EPL makes employment adjustments more costly.

While the theoretical literature is ambiguous about the impact of EPL on the overall level of innovative activity, it clearly points to a detrimental effect of EPL on more technologically advanced or risky investments. To empirically investigate this prediction we also estimate

$$NPL_{ms} = \exp\left(\beta EPL_c + \gamma \ln CITWP_{ms} + X_{ci} + \eta_m + \nu_{ms}\right) \tag{28}$$

where NPL is a weighted count of patents that gives a greater weight to patents that are more technologically advanced (discussed further in the next section). More specifically, NPL is a count of patents weighted by the number of citations made to non-patent literature, mainly scientific journals. CITWP is the count of patents from (27) weighted by all citations made, to control for heterogeneity across patents in the amount of citations made. Our main interest is the sign and magnitude of β - a negative sign would indicate that higher technologically advanced patenting, as a proportion of overall patenting, is associated with lower EPL.

One concern we might have with estimating equations (27) and (28) is that EPL is correlated with other institutional variables that also affect innovation incentives. We have available country level measures of other labour market regulations. We also have a measure of product market regulations, a measure of concentration in the banking sector and a measure of the efficiency of the courts, which may affect the value of holding a patent.[113] Some of these variables are highly correlated with EPL as we can see from the correlation matrix in Table 1 and it is therefore challenging to separately identify the effect of EPL, as with all studies using cross-country variation in this way (variable definitions and sources are in Table A1). EPL is particularly highly correlated with collective bargaining coverage and bargaining coordination, which have been found to be determinants of worker bargaining power,[114] and with the OECD overall measure of product market conditions. Nevertheless, our results are robust to controlling for these institutional variables.

[113] See Aghion et al. (2005) for the effect of product market regulations that determine competition on innovation. See Carlin and Mayer (2003) for the effect of banking concentration on specialisation in high tech innovative sectors.

[114] See Calmfors and Driffil (1998), see Flanagan (1999) for Chapter 2 of this thesis for evidence that bargaining coordination increases worker bargaining power.

Table 1: Employment Protection Legislation and Control Variables

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Employment Protection Legislation (Regular Contracts)	(1)	1.00										
Union Density - Average 1997-2003	(2)	-0.22	1.00									
Collective Bargaining Coverage	(3)	0.63	0.05	1.00								
Employment Tax Wedge - Average 1997-2003	(4)	0.33	0.24	0.87	1.00							
Bargaining Coordination	(5)	0.73	0.09	0.59	0.39	1.00						
OECD Product Market Regulations 1998&2003 Average	(6)	0.57	-0.36	0.63	0.53	0.36	1.00					
Credit Institutions per Capita - Average 1997-2002	(7)	0.19	0.52	0.36	0.17	0.52	-0.14	1.00				
Percent of Claim Spent in Court and Attorney Fees (where mandatory)	(8)	0.10	0.07	-0.20	0.05	-0.03	-0.04	-0.40	1.00			
Log of Real Capital per thousand workers, 2000 USD, 1995 prices, in year 1997	(9)	0.42	0.27	0.65	0.46	0.44	0.38	0.36	-0.47	1.00		
Log of Share of GDP Spent on Higher Education	(10)	0.16	0.47	0.28	0.26	0.17	-0.45	0.43	0.16	0.06	1.00	
Average working population (mil.) 1997-2003	(11)	0.09	-0.74	-0.07	-0.06	-0.18	0.25	-0.43	0.01	-0.40	-0.41	1.00

Notes: see table A1 for full descriptions and sources.

A further concern we might have is that differences in country-industry specialization may influence our results. The trade literature emphasises that countries with a large endowment of capital or skills have an advantage in industries that are capital or skill intensive, which may include high-tech. We follow Nunn (2007) and use capital abundance and investment in skills at the country level interacted with estimates of industry capital and skill intensity. Another concern is that country size may be correlated with EPL, and production activity locates in large countries to access the product market, and where this production is highly skilled it drives up wages for high skilled workers in those countries (e.g. see Ekholm and Hakkala, 2007). As market access is less important for R&D this may crowd out highly skilled innovation to smaller countries. To control for country size we include population. These considerations lead to the following structure for X_{ci}:

$$X_{ci} = \alpha_1 k_i + \alpha_2 k_i K_c + \alpha_3 K_c + h_i + \alpha_4 h_i H_c + \alpha_5 H_c + \alpha_6 Pop_c, \qquad (29)$$

where k_i is the capital per unit output in industry *i* based on US data (the US is not in the sample), K_c is the natural log of the capital per worker in country *c*, h_i is the skill intensity of industry *i*, H_c is the natural log of the proportion of GDP spent on higher education in country *c*, and Pop_c is the working population of country *c* averaged over the sample period.

4. DATA

In order to estimate equations (27) and (28) we need information on the geographic location and level of technological sophistication of MNEs' innovative activity, along with information on EPL and other country and industry characteristics.

4.1. Measuring the innovative activity of MNEs

The data on patents come from the EPO PATSTAT dataset which we have matched to information on corporate ownership structure and financial accounts from BVD Amadeus (see Chapter 1 of this thesis). Patents filed at the European Patent Office (EPO) are a particularly attractive measure of innovative activity. The advantage of this measure is that it is administrative in nature with well defined rules that are independent of the location of the patent applicant. Furthermore, it is measured at the firm level (in constrast data on firm level R&D expenditure is not widely available for firms in many European countries). Patents data has been widely used and found to be closely related to R&D expenditure measures, and this is true for our data at the industry level (see Chapter 1 of this thesis).

Of the 37,350 patenting firms in our sample 11,489 have an identifiable ultimate owner. Of these, 2,933 are part of a MNE with at least two subsidiaries in different countries. Of these firms, 1,378 firms file at least one patent that makes at least one citation.[115] Table 2 shows how the firms and patent applications are distributed across countries. Column (3) lists how the 1,378 firms that make up our baseline MNE sample are distributed across countries and column (4) lists their patent application counts. The baseline sample includes all patent applications whether or not they have been granted, although we have checked the robustness of our results to using only granted patents (available from the authors on request).

Table 2: Firms and Patents

Country	Number of firms (1)	Number of patents filed (2)	Number of firms in MNEs (3)	Number of patents filed by firms in MNEs (4)
Belgium	853	4,583	36	622
Germany	11,592	108,431	491	12,998
Denmark	1,151	4,160	40	380
Spain	1,149	2,084	34	181
Finland	869	8,032	5	72
France	4,043	31,310	322	10,536
United Kingdom	7,964	23,857	228	2,766
Italy	4,556	11,833	89	1,027
Netherlands	2,103	21,442	64	1,765
Norway	689	1,362	5	54
Portugal	54	96	2	25
Sweden	2,327	13,132	62	2,131
Total	37,350	230,322	1,378	32,557

115 We show that our results are robust to relaxing this condition by also running regressions using all subsidiaries that patent, regardless of whether or not they make citations.

To estimate equation (27) we measure innovative activity as a simple count of patents (*P*). We use simple counts rather than weighting patents by citations *received* as many of the patents are relatively new and have not yet received the citations that they will do in the future. However our results are robust to using citations weighted patents, suggesting that the effect is significant for economically valuable patents. To estimate equation (28) we measure *radical* innovation activity (NPL_{ms}) as a count of non-patent literature (NPL) citations *made* by patents filed by subsidiary *s* in MNE *m* over the sample time period, and we control for the total number of citations *made* by the same patents. This measure is an indicator of the newness of the innovation, since NPL citations are typically citations to scientific journals. Table 3 shows how the proportion of all citations made that are to NPL varies across industries. We can see that industries which we might expect to require highly scientific innovation, such as food production, transport and communications, finance and chemical (including pharmaceuticals) have the highest proportion of NPL citations, and industries which we might expect to involve less scientific innovations, such as light manufactures, have the lowest proportion of NPL citations.

Table 3: Industries and Non-Patent Literature Citations

INDUSTRY	Percent of Citations to Non-Patent Literature
FOOD PRODUCTS, BEVERAGES AND TOBACCO	0.26
TRANSPORT AND STORAGE AND COMMUNICATION	0.22
FINANCE, INSURANCE, REAL ESTATE AND BUSI	0.19
CHEMICALS AND CHEMICAL PRODUCTS	0.17
BASIC METALS	0.15
ELECTRICAL AND OPTICAL EQUIPMENT	0.14
ELECTRICITY, GAS AND WATER SUPPLY	0.13
WHOLESALE AND RETAIL TRADE; RESTAURANTS	0.11
COKE, REFINED PETROLEUM PRODUCTS AND NUC	0.10
MOTOR VEHICLES, TRAILERS AND SEMI-TRAILE	0.10
OTHER TRANSPORT EQUIPMENT	0.10
CONSTRUCTION	0.09
OTHER NON-METALLIC MINERAL PRODUCTS	0.09
MACHINERY AND EQUIPMENT, NEC	0.08
PUBLISHING, PRINTING AND REPRODUCTION OF	0.08
RUBBER AND PLASTICS PRODUCTS	0.08
TEXTILES, TEXTILE PRODUCTS, LEATHER AND	0.07
FABRICATED METAL PRODUCTS, EXCEPT MACHIN	0.06
PAPER AND PAPER PRODUCTS	0.06
WOOD AND PRODUCTS OF WOOD AND CORK	0.06
MANUFACTURING NEC	0.05

Notes: The values are estimated using the years 1997 to 2003.

Our interest in this paper is on the effect of labour market regulations that affect job security for workers and adjustment costs for employees. Increased job security increases worker incentives to invest in innovation and therefore increases the return to innovation for employers. However, where innovation is uncertain or significantly new, in that it requires an adjustment in the skill mix of employees which may involve the replacement of existing workers with external workers, regulations that protect existing employment increase the cost of innovation. Our expectation is that the second effect will dominate the first when innovation is significantly technologically advance, as measured by the proportion of citations to NPL. Table 4 supports the appropriateness of this measure. From column (1) we see that high NPL innovation is significantly positively correlated with the average number of inventors per patent, indicating its complex nature. Column (2) indicates that NPL innovation is correlated with employment adjustment within firms and column (3) indicates that NPL innovation is correlated with country-sector uncertainty, as measured by sales volatility.

Table 4: NPL Citations, complexity, adjustment and uncertainty

	Average no of inventors per patent	Within firm employment volatility	Within firm sales volatility
	(1)	(2)	(3)
Proportion of citations to non-patent literature	0.2681	0.1158	0.1919
P-val	0.0000	0.0000	0.0000

Notes: Observations are country-3 digit industries. The values are estimated using the years 1997 to 2003. Column (2): employment volatility is the country-industry average coefficient of variation in employment calculated for each firm over the time period. Column (3): sales volatility is the country-industry average coefficient of variation in sales calculated for each firm over the time period.

4.2. Employment Protection Legislation

We use an index of EPL calculated by the OECD (see OECD Economic Outlook 1999 Chapter 2) and widely used in the literature on the determinants of unemployment (Nickell et al. 2005).[116] Our preferred measure is an average of an indicator of the legislation for regular contracts (covering procedural inconveniences, direct cost of dismissal, notice and trial period). Our results are also robust to using the higher level indicator that also includes legislation for temporary contracts (covering types of work admissible under temporary contracts and maximum cumulative duration allowed). Key for our purposes is that there is real variation in this measure across the countries in our sample, as is clearly evident from Figure 1.

5. RESULTS

To recap, we have hypothesized an effect on innovation of EPL that is differential across the nature of innovation. On the one hand EPL may increase overall patenting, but on the other hand it may reduce risky radical innovation. To see whether we find empirical support for these ideas we estimate equations (27) and (28), controlling for multi-national enterprise (MNE) fixed effects and cross country characteristics.

The results for equation (27) are presented in Table 5. Column (1) shows results for a simple specification with MNE fixed effects. The positive coefficient on EPL indicates that within MNEs more innovation is performed by subsidiaries in countries with high

[116] Its theoretical effect on unemployment is ambiguous as it may both limit flows into unemployment and increase worker bargaining power leading to high wage demands, and empirical evidence is mixed (as mentioned in Nickell 2005, also see Blanchard 2005 for discussion).

employment protection for workers. Column (2) shows that this is robust to controlling for other institutional variables and population. Column (3) shows that controlling for the interaction of capital abundance with industry capital intensity, and the interaction of investment in higher education interacted with industry skill intensity, to ensure our result is not driven by other patterns of comparative advantage (Portugal's two observations drop out as there is no higher education expenditure data). The result is robust to the inclusion of institutional control variables in column (2). The coefficient on the interaction of capital abundance and capital intensity is positive as we would expect. The coefficient on the interaction of higher education expenditure and skill intensity is negative. Although the coefficient on EPL retains its sign it loses magnitude and statistical significance. Statistical significance is retained in both cases if the regression is run with, firstly, just the capital variables and, secondly, just the skills variables.

Table 5: Employment Protection Legislation and Innovation

Dependent Variable:	All Patent Application (1)	All Patent Application (2)	All Patent Application (3)
Employment Protection Legislation (Regular Contracts)	0.4417	0.8479	0.1670
	[0.1220]***	[0.4543]*	[0.1223]
Union Density - Average 1997-2003		-0.0216	
		[0.0168]	
Collective Bargaining Coverage		-0.0095	
		[0.0452]	
Employment Tax Wedge - Average 1997-2003		0.1222	
		[0.1213]	
Bargaining Coordination		-1.0381	
		[0.2029]***	
OECD Product Market Regulations 1998&2003 Average		-1.3472	
		[0.7726]*	
Credit Institutions per Capita - Average 1997-2002		16.9807	
		[12.1849]	
Percent of Claim Spent in Court and Attorney Fees (where mandatory)		0.0451	
		[0.0298]	
Average working population (mil.) 1997-2003		-0.0047	0.0036
		[0.0092]	[0.0068]
Log of Real Capital per thousand workers, 2000 USD, 1995 prices, in year 1997			-0.3157
			[0.7646]
Log of Capital per worker at 1997*Industry capital intensity			0.6179
			[0.3523]*
Industry Capital Intensity			-2.8126
			[1.5490]*
Log of Share of GDP Spent on Higher Education			1.840
			[0.4307]***
Log of Share of GDP Spent on Higher Education*Industry skill intensity			-3.4159
			[1.1935]***
Industry Skill Intensity			-1.9069
			[1.2660]
Constant	0.7452	0.4226	5.2746
	[0.0976]***	[0.7208]	[3.3580]
MNE Fixed Effects	Yes	Yes	Yes
Observations	1378	1378	1376

Notes: All columns show the results of Poisson regression with robust standard errors clustered at the country level. In column (3) Portugal is excluded due to a lack of data on expenditure on education.

Table 6 shows the results for equation (28). The dependent variable is now a measure of risky innovation - the number of citations to the non-patent literature, with the log of the total number of citations as a control, so that we can interpret the results as the effect of EPL on the proportion of citations that are to NPL. In column (1) the negative coefficient on EPL indicates that within MNEs more technologically advanced innovation is performed by subsidiaries in countries with low employment protection for workers. The result is robust to the inclusion of institutional control variables in column (2). The coefficient on the interaction of capital abundance and capital intensity is positive as we would expect. The coefficient on the interaction of higher education expenditure and skill intensity is positive, but not significant.

Table 6: Employment Protection Legislation and Radical Innovation

Dependent Variable:	NPL Citations	NPL Citations	NPL Citations
	(1)	(2)	(3)
Employment Protection Legislation (Regular Contracts)	-0.1245	-0.3706	-0.0671
	[0.0414]***	[0.2099]*	[0.0353]*
Log of All Citations Made	1.0013	1.0175	1.0142
	[0.0194]***	[0.0096]***	[0.0118]***
Union Density - Average 1997-2003		0.0083	
		[0.0065]	
Collective Bargaining Coverage		0.0603	
		[0.0265]**	
Employment Tax Wedge - Average 1997-2003		-0.0946	
		[0.0640]	
Bargaining Coordination		0.2466	
		[0.1432]*	
OECD Product Market Regulations 1998&2003 Average		-0.6723	
		[0.1628]***	
Credit Institutions per Capita - Average 1997-2002		-20.0452	
		[6.6221]***	
% of Claim Spent in Court and Attorney Fees (where mandatory)		0.035	
		[0.0063]***	
Average working population (mil.) 1997-2003		0.0028	-0.0077
		[0.0050]	[0.0017]***
Log of Real Capital per thousand workers, 2000 USD, 1995 prices, in year 1997			-0.6234
			[0.2740]**
Log of Capital per worker at 1997*Industry capital intensity			0.3523
			[0.1532]**
Industry Capital Intensity			-1.549
			[0.6991]**
Log of Share of GDP Spent on Higher Education			-0.0221
			[0.2738]
Log of Share of GDP Spent on Higher Education*Industry skill intensity			0.9525
			[1.1952]
Industry Skill Intensity			1.412
			[1.2615]
Constant	-0.8759	-2.9932	0.6033
	[0.1148]***	[0.2334]***	[1.2219]
MNE Fixed Effects	Yes	Yes	Yes
Observations	1378	1378	1376

Notes: All columns show the results of Poisson regression with robust standard errors clustered at the country level. In column (3) Portugal is excluded due to a lack of data on expenditure on education.

What is the economic significance of these estimates? To consider this we look at the impact of moving each country to the mean EPL index of 2.3. Consider countries like Italy and Germany, which have relatively strong employment protection legislation, so that the EPL index measure is 2.8. Reducing their EPL to the mean in our sample of 2.3

would result in approximately a 20% fall in overall patents (using the coefficient estimates in column (2) of Table 5 evaluated at the mean level of patenting), but an increase in radical innovations of around 5%.

Consider a country like Denmark with a low amount of employment protection, which has an EPL index of 1.6, increasing their EPL index to 2.3 would lead to an increase in overall patenting of around 37%, but a fall in radical innovations of around 6%. These are substantial effects.

6. CONCLUSION

This paper has investigated the relationship between employment protection legislation and innovation activity across twelve European countries. We use unique data on the activities of multinational firms operating across different jurisdictions. Our findings suggest that multinational firms do more incremental patenting activity in high EPL countries and more radical patenting activity in low EPL countries. This is consistent with a variant of an Aghion and Howitt style growth model that we outline. However, it is also consistent with other theoretical models, such as Saint-Paul's model of comparative advantage, and with the ideas put forward in Hall and Soskice.

Care must be taken in interpreting these results. While we have attempted to control for a number of other characteristics that vary across countries, and for firm specific characteristics, identification is still from cross-sectional data. We do not observe sufficient time series variation in EPL and our data to identify the effects of changes in labour market regimes. Nonetheless, this evidence is suggestive and appears to be robust to a number of standard concerns put forward in the literature.

APPENDIX

In a similar vein to Boeri and Jimeno (2005) consider that there is a small probability *p* that demand for the final good will drop from high, θ^h, to low, θ^l.[117] So that $y_t = \theta^S \int_0^1 (ZA_{it})^{1-\alpha} x_{it}^{\alpha} di$, $S = h,l$. On the realisation of the demand shock the firm will wish to adjust employment from x^h to the new optimal level x^l by firing workers. The probability for each worker of being fired is then given by:

$$s = p.\left(\frac{x^h - x^l}{x^h}\right). \tag{A1}$$

In the presence of EPL it costs the firm φ per worker to adjust employment downwards. The loss to the firm of a non-optimal level of employment, *x*, is given by:

$$\Delta\pi = \left(\theta^l \alpha (ZA)^{1-\alpha} x^{\alpha-1} - 1\right)x - \left(\theta^l \alpha (ZA)^{1-\alpha} \left(x^l\right)^{\alpha-1} - 1\right)x^l , \tag{A2}$$

where the first term is the level of profits given low demand but with employment $x > x^l$ and the second term is the level of profits given low demand and the optimal level of employment. When $x = x^l$, $\Delta\pi = 0$. The firm faces firing costs given by $-\varphi\left(x^h - x\right)$. The firm will adjust the employment level until the marginal gain from doing so equals the marginal cost of firing an employee. The optimal level of employment, $\hat{x}$, given firing costs is then given by:

$$\theta^l \alpha^2 (ZA)^{1-\alpha} \hat{x}^{\alpha-1} - 1 = -\varphi \tag{A3}$$

Therefore,

$$\hat{x} = \left(\frac{1-\varphi}{\theta^l \alpha^2}\right)^{\frac{1}{\alpha-1}} ZA . \tag{A4}$$

This expression is increasing in φ. Note that it reduces to x^l in the absence of firing costs ($\varphi = 0$). There will also exist some level of φ where no adjustment occurs. Substituting this into (A1) gives the probability of being fired faced by each worker in the presence of firing costs:

[117] This is simpler than Boeri and Jimeno (2005) in that we consider that demand is normally high, but there is a small possibility that it drops. The firm initially chooses employment levels assuming demand will be high.

$$s = p.\left(\frac{\left(\frac{1}{\theta^h \alpha^2}\right)^{\frac{1}{\alpha-1}} ZA - \left(\frac{1-\varphi}{\theta^l \alpha^2}\right)^{\frac{1}{\alpha-1}} ZA}{\left(\frac{1}{\theta^h \alpha^2}\right)^{\frac{1}{\alpha-1}} ZA} \right) = p.\left(1 - \left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} (1-\varphi)^{\frac{1}{\alpha-1}} \right). \qquad \text{(A5)}$$

This probability decreases as $\theta^l \to \theta^h$ as we would expect.[118] Writing out $s(\varphi)$ followed by its first and second derivatives:

$$s(\varphi) = p.\left(1 - \left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} (1-\varphi)^{\frac{1}{\alpha-1}} \right), \qquad \text{(A6)}$$

$$s'(\varphi) = p.\frac{1}{(\alpha-1)}\left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} (1-\varphi)^{\frac{2-\alpha}{\alpha-1}}, \qquad \text{(A7)}$$

$$s''(\varphi) = -p.\frac{(2-\alpha)}{(\alpha-1)^2}\left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} (1-\varphi)^{\frac{3-2\alpha}{\alpha-1}}. \qquad \text{(A8)}$$

As $\alpha < 1$ and restricting $\varphi \in [0,1)$ we have $s'(\varphi) < 0, s''(\varphi) < 0$, that is the probability of a worker losing their job is decreasing in φ and at an increasing rate.[119]

Using a Taylor expansion around $\varphi = 0$ we can write this as:

$$s = p.\left(1 - \left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} \right) - p.\frac{1}{(1-\alpha)}\left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} \varphi - p.\frac{1}{2}\frac{(2-\alpha)}{(\alpha-1)^2}\left(\frac{\theta^h}{\theta^l}\right)^{\frac{1}{\alpha-1}} \varphi^2 .... \qquad \text{(A9)}$$

[118] The probability of being fired is non-positive when $\theta^l = \theta^h$. Note that $\alpha < 1$.

[119] Restricting firing costs to be between zero and one is natural here as the workers reservation wage is normalised to one and it is likely that firing costs will be some proportion of that. *s* tends to negative infinity as firing costs tend to one, but we just exclude this and say that at some point firing costs are so high that the firm does not adjust employment at all.

Table A1: Data and Sources

Variable	Description and source	Mean s.d.
Employment Protection Legislation (Regular Contracts)	An average of an indicator of legislation for regular contracts (covering procedural inconveniences, direct cost of dismissal, notice and trial period) and an indicator for legislation for temporary contracts (covering types of work admissible under temporary contracts and maximum cumulative duration allowed). Nicoletti et al (2000).	2.425 .89048
Union Density - Average 1997-2003	Actual union members as percentage of employees. OECD Labour Force Statistics.	42.10833 25.38686
Collective Bargaining Coverage	Percentage of employees covered by collective bargaining, whether they are union members or not. Nickell (2003), originally obtained from Wolfgang Ochel.	79.66667 15.69211
Employment Tax Wedge - Average 1997-2003	Average of the tax wedge for one-earner family with two children and single persons without children. OECD, Taxing Wages, 2003.	38.74788 6.950881
Bargaining Coordination	The degree of coordination of bargaining: 1- firm level, 2- industry level, 3- economy level. We use coordination index 2 from Nickell (2003), originally obtained from Wolfgang Ochel.	2.083333 .5149287
OECD Product Market Regulations 1998&2003 Average	Top level indicator capturing extent of state control of product markets, barriers to entrepreneurship and trade and investment. Source: OECD International Regulation Database.	1.700718 .3538945
Credit Institutions per Capita - Average 1997-2002	Credit institutions are defined by the European Central Bank as any institution covered by the definition contained in Article 1(1) of Directive 2000/12/EC, as amended. Accordingly, a credit institution is "(i) an undertaking whose business is to receive deposits or other repayable funds from the public and to grant credits for its own account; or (ii) an undertaking or any other legal person, other than those under (i), which issues means of payment in the form of electronic money." Source: CESIfo Dataset, see http://www.cesifo.de. For Norway, from Eitrheim et al. (2003).	.0404272 .0255226
% of Claim Spent in Court and Attorney Fees (where mandatory)	The estimated cost of suing for breach of contract in a hypothetical case as a percentage of the claim amount. Source: Doing Business Report. See http://www.doingbusiness.org/ExploreTopics/EnforcingContracts/ for data and exact methodology	19.44167 7.113554
Average working population (mil.) 1997-2003	Source: OECD.	19.92361 18.70212
Real Capital per thousand workers, 2000 USD, 1995 prices, in year 1997	For total economy, averaged over sample period. Calculated using a permanent inventory method using gross fixed capital formation. In units of 2000 USD at 1995 prices. Source: OECD Stan.	108.1972 30.38796
Industry Capital Intensity	Capital divided by output for each industry using US data, average over the sample period. Source: OECD Stan.	1.16211 .6363175
Share of GDP Spent on Higher Education	As a proportion of GDP. Averaged over 1991-1995, making it pre-sample period. Source: OECD.	.3635136 .1318802
Industry Skill Intensity	Proportion of workers in each two digit industry in the United Kingdom in 2000 with degree or other higher education. Source: UK Labour Force Survey.	.250483 .128509

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