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PATENT RIGHTS, PRODUCT MARKET REFORMS, AND INNOVATION

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ABSTRACT

Can patent protection and product market competition complement each other in enhancing incentives to innovate? In this paper, we address this question by investigating how innovation responses to a substantial policy initiative increasing product market competition interact with the strength of patent rights. We provide empirical evidence of innovation responding positively to the product market reform in industries of countries where patent rights are strong, not where these are weak. The positive response to the reform is more pronounced in industries in which innovators rely more on patenting than in other industries, and in which the scope for deterring entry through patenting is not too large. Our empirical findings are in line with step-by-step innovation models predicting that product market competition enhances innovation and, more importantly, that patent protection can complement competition in inducing innovation.

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1 Introduction

Over the past three decades, numerous changes to patent systems have strengthened patent protection worldwide.[1] While this is in line with the common view that patent protection should enhance innovation incentives, empirical studies investigating the effects of such regulatory changes on the level of innovation have hardly found evidence of positive average effects (Sakakibara and Branstetter, 2001, Lerner, 2002 and 2009, and Qian, 2007, among others). As Josh Lerner (2009, p. 347) put it: "The lack of a positive impact of strengthening of patent protection on innovation is a puzzling result. It runs (...) against our intuition as economists that incentives affect behavior (...)."

In this paper we set out to study whether patent protection can foster innovation when being complemented by product market competition. More specifically, we investigate how innovation responses to a competition-increasing product market reform depend upon the strength of patent rights. The product market reform that we consider was part of the European Single Market Program (SMP). The European Commission designed this large scale policy initiative to enhance competition, innovation and economic growth and implemented it in 1992, a time with significant variation in patent protection across European Countries. The product market reform created exogenous variation in product market conditions not only across time, but also across industries and countries. Positive average effects on product market competition have been documented (Badinger, 2007, Bottasso and Sembenelli 2001, and Griffith, Harrison and Simpson 2010, among others).

In our empirical analysis, we first compare the innovation responses to the product market reform across two country groups. The first group covers the countries with strong patent rights in our main sample of 13 manufacturing industries in 17 European countries between 1987 and 2003. These countries have had strong intellectual property rights (IPR) regimes

[1] These changes involve, among others, improvements to patent enforcement, the lengthening of the patent term or the broadening of patent scope. In addition, patent protection now also covers innovation types that were previously largely non-patentable, and it is reaching out to public research communities in many countries and to developing countries.

since the pre-sample period, 1980 until 1986, and are among the founder states of the European Patent Organisation (EPOrg). The second group covers the countries with weaker patent rights before and during our observation period. The estimation results indicate that innovation responds positively to the competition-enhancing product market reform in industries that are located in countries with strong patent rights, but not so in industries of countries with weaker patent rights.[2] A concern with these reform effects which differ between country groups could be potential interactions between the product market reform and factors other than the country-specific strength of patent protection. We address this concern by investigating the variation of the reform effects across industries. The reform effect in countries with strong patent rights should be more pronounced in industries where innovators are generally more prone to rely on patenting and are likely to value strong patent protection more than in other industries.[3] We find empirical evidence in line with this prediction. In addition, we find that the more pronounced innovation responses in industries with higher patent relevance arise only as long as the scope for deterring entry through patenting is not too large. In this paper, we argue that all these empirical findings are consistent with Schumpeterian growth models with step-by-step innovation where patent protection and product market competition can become complementary forces.

The view that patent protection and product market competition should act as complementary inputs to innovation and growth, is at odds with what early endogeneous growth models would predict (e.g., Romer, 1990, and Aghion and Howitt, 1992). In these models patent protection fosters innovation and growth as it enhances the rents from innovation, whereas product market competition deters innovation and growth by reducing these rents. Thus, patent protection is good for innovation for exactly the same reason that renders competition bad for innovation. More recently, Boldrin and Levine (2008) have argued that patent protection is detrimental to innovation because it blocks product market competition

[2] We find consistent results when measuring innovation by research and development (R&D) intensity, real R&D expenditures, or the number of patents.

[3] To identify these industries in which patent relevance is high in general and for exogenous technological reasons we use the pre-sample patent intensity in the corresponding US industries.

whereas competition is good for innovation because it allows the greatest scope to those who can develop new ideas. Even though Boldrin and Levine (2008) depart here from the endogenous growth literature, they share the view that patent protection and competition are counteracting (or mutually exclusive) forces: namely, whenever one is good for innovation the other is detrimental to innovation.[4]

However, patent protection and product market competition can become complementary forces in a Schumpeterian growth model with step-by-step innovation. Why? Because in such a model a positive fraction of sectors involve neck-and-neck firms, that is, firms that compete on an equal technological footing. Each firm's incentive to innovate depends on the difference between its post-innovation rent and its pre-innovation rent, and this difference - the net innovation rent - is in turn affected by both, product market competition and patent protection. More specifically, in a neck-and-neck sector where firms make positive profits even if they do not innovate, tougher product market competition will reduce this pre-innovation rent. It may also lower the post-innovation rents but to a lower extent. Thus, overall, product market competition will increase the net innovation rents in a neck-and-neck sector: this we refer to as the escape competition effect in Aghion, Harris, Howitt and Vickers (2001) and Aghion, Bloom, Blundell, Griffith and Howitt (2005). On the other hand, stronger patent protection will enhance post-innovation rents to a larger extent than pre-innovation rents, especially when the latter are bogged down by competition. Hence, there is complementarity between product market competition and patent protection in inducing innovation. This contrasts with the model of Romer (1990) in which innovations are made by outsiders who create a new variety, and with the model of Aghion and Howitt (1992) in which innovators leap-frog incumbent firms. In both these models, the pre-innovation rent is zero and product market competition deters innovation by reducing the post-innovation rent which represents the net innovation rent.

Our paper contributes to several strands of literature. First, it contributes to the lit-

[4]See our discussion in Aghion, Howitt and Prantl (2013).

erature on competition and growth.[5] Aghion et al. (2005) report empirical evidence of an inverted-U relationship between product market competition and innovation in the United Kingdom (U.K.). Aghion, Blundell, Griffith, Howitt and Prantl (2009) study how escape-entry effects on the productivity growth and patenting of incumbent establishments and firms in the U.K. vary with their level of technological development. Aghion, Burgess, Redding and Zilibotti (2008) show that the effect of an Indian product market deregulation on industry output varies with the institutional characterstics of Indian states. Focussing on the SMP, like we do,[6] Bottasso and Sembenelli (2001) and Badinger (2007) show that this product market intervention reduced mark-ups in manufacturing industries. Griffith et al. (2010) report that the SMP enhanced product market competition which, in turn, led to an increase in R&D expenditures, using panel data for manufacturing industries in OECD countries.[7] None of these papers, however, examines how the impact of a competition-increasing product market reform on innovation may interact with the strength of patent protection.

Our work also contributes to the empirical literature on the effects of intellectual property rights (IPR), as well as IPR reforms, on the level of innovation.[8] Sakakibara and Branstetter (2001) investigate consequences of the Japanese patent law reform in 1988. The reform introduced the option of multiple, (in)dependent claims per patent and, thus, broadened the scope of Japanese patents. They find no evidence of positive average reform effects on R&D spendings of Japanese firms. What they do not consider is a potential interaction between the patent reform and product market competition. Branstetter, Fisman and Foley (2006) focus on a different research question, investigating how the extent of technology transfers

[5] See Aghion et al. (2001) and Acemoglu, Aghion and Zilibotti (2006), in particular, but also Acemoglu (2009), Aghion and Howitt (2009) and Acemoglu and Akcigit (2012). With regard to the related theoretical literature in industrial organization, we refer the reader, among others, to Tirole (1988), Scotchmer (2004), Gilbert (2006), Vives (2008), and Schmutzler (2010, 2012).

[6] In Aghion et al. (2005, 2009), the SMP provides the excluded instruments that are used in instrumental variable and control function models explaining innovation or productivity growth.

[7] To capture product market competition, Griffith et al. (2010) use the following inversely related measure: average profitability at the country–industry–year level, defined as value-added divided by labour plus capital costs.

[8] Moser (2005) addresses an important, but different question. She provides empirical evidence suggesting that the existence of patent laws influences the direction of technological progress, as well as the pattern of comparative advantages across countries.

within United States (U.S.) multinational firms responds to IPR reforms in their affiliates' host countries. Both these papers inspired our empirical approach in one respect. We allow for differences in innovation responses across industries that differ in the propensity of patenting, and therefore the relevance of patent protection, as this contributes to our identification of the interaction effects between patent rights and the product market reform. Qian (2007) uses country-level panel data for the pharmaceutical industry in OECD countries to show that introducing national patent protection does, on average, not stimulate pharmaceutical innovation. Interestingly, she finds positive, often statistically significant coefficients on interactions between patent protection and the country-level Fraser Institute index of economic freedom.[9] To the extent that this index can reflect country-level freedom to compete and trade the latter finding for the pharamceutical industry provides a first hint towards the interaction effects we are interested in. Against this background, we focus on identifying the interactions between product market competition and patent protection, exploiting the fact that the SMP product market reform created exogenous variation in product market conditions across industries, countries and time.

The remainder of the paper is organized as follows. In the next section, we explain the theoretical argument in greater detail. Section 3 presents the empirical model and, in section 4, we briefly explain the data and show descriptive statistics. The empirical results and their discussion follow in section 5. In section 6, we summarize and conclude.

[9] This index is a composite measure which aggregates country-level proxies of the size of government, access to money, regulation of credit, labor and business, legal structure and property rights, and freedom to trade.

2 Theoretical argument

In this section, we sketch a simple model to think about the relationship between the strength of patent rights, reforms increasing product market competition, and innovation.[10]

2.1 Basic setup

Time is discrete and the economy is populated by a continuum of people who all live for one period. In each period t a final good Y, henceforth the numéraire, is produced under perfect competition from a continuum of intermediate inputs, according to the technology

$$Y_t = \int_0^1 {A_{it}}^{1-\alpha} {x_{it}}^{\alpha} \, di$$

where x_{it} is the quantity of the intermediate input produced in industry i in period t and $\alpha \in (0,1)$. With A_{it} we denote the productivity parameter associated with the latest version of intermediate good i. The final good in turn is used for consumption, as an input to the innovation process, and as an input to the production of intermediate goods.

In each intermediate industry i, only a monopolist produces in each period, using a one-to-one technology. Thus, the variable i refers both, to an intermediate industry, and to the intermediate firm which is active in that industry. As any other agent in the economy, intermediate producers live for one period only and technological capabilities are transmitted within dynasties. Each intermediate firm chooses how much to produce in order to maximize profits, taking into account that the price at which it can sell its intermediate good to the final good production is equal to the value of the marginal product of that good in final good production.

Profit maximization yields an equilibrium profit for each intermediate firm i in period t which is equal to

$$\pi_{it} = q\pi A_{it} \tag{1}$$

where

[10] The section builds on Acemoglu et al. (2006) and Aghion et al. (2001).

$$\pi = \left(\frac{1-\alpha}{\alpha}\right)\alpha^{\frac{2}{1-\alpha}}$$

and q is the probability that innovation profits are not expropriated (Acemoglu et al. 2006). This variable reflects the strength of patent rights.

Before a firm decides on production in period t, it can invest in R&D to increase its productivity. A firm's productivity at the beginning of period t is A_{t-1} and each innovation increases the productivity by factor γ, assuming $A_t = \gamma A_{t-1}$ with $\gamma > 1$. For innovation to be successful with probability z an intermediate firm in period t must invest

$$c_t = cz^2 A_{t-1}/2 \text{ where } c < 1. \tag{2}$$

Intermediate firms are subject to an entry threat from new producers. Let p denote the probability that an entrant shows up. We take p to be exogenous and new entrants in period t are assumed to operate with productivity A_{t-1} in t.

Entry is deterred with probability one if the incumbent in industry i innovates. If the incumbent does not innovate and, therefore, the incumbent and the entrant have the same productivity A_{t-1}, entry is deterred with probability βq, where β indicates the marginal deterrence effect of patent protection on entry. The idea is that the stronger the patent system, the more likely will entry be deterred. This negative effect of patent protection on entry is emphasized by Boldrin and Levine (2008).[11] Therefore, the probability of actual entry in an intermediate industry i, is equal to zero if the incumbent i has innovated, and it is equal to $p(1-\beta q)$ otherwise. We assume that if entry occurs, the incumbent's profit falls to zero through Bertrand competition. An increase in p, reflecting an increase in entry threat, corresponds to an increase in product market competition.

[11] We implicitly assume that potential entrants observe the post-innovation technology of the incumbent firm before deciding whether or not to enter. Then, the potential entrant will find it profitable to enter only if the incumbent has not innovated. However, she will never enter in period t if the incumbent has innovated.

2.2 The interplay between patent protection and competition

Using equation (1) for the equilibrium profit, together with the innovation technology in equation (2), we can analyze incumbent firms' R&D investment decisions. If an incumbent firm successfully innovates, then its profit will be $\pi\gamma A_{t-1}$ with probability q. If the incumbent fails to innovate, then its profit will be πA_{t-1} with probability $q[1-p(1-\beta q)]$. This is the probability that the incumbent is not expropriated times the probability that entry does not occur or is not successful. Therefore, the incumbent's expected profit, including the cost of innovation, is equal to

$$zq\pi\gamma A_{t-1} + (1-z)\,q[1-p(1-\beta q)]\pi A_{t-1} - cz^2 A_{t-1}/2.$$

The incumbent firm will choose the probability z that maximizes this expression. The first-order condition of this maximization problem yields the probability

$$z = \frac{\pi q}{c}[\gamma - 1 + p(1-\beta q)]. \tag{3}$$

Differentiation of the equilibrium innovation probability with respect to q yields

$$\frac{\partial z}{\partial q} = \frac{\pi}{c}\{\gamma - 1 + p - 2p\beta q\}. \tag{4}$$

Accordingly, the strength of patent rights, as measured by q, has a priori an ambiguous effect on innovation incentives, even though the effect is positive for β sufficiently small $(\beta < (\gamma - 1 + p)/2pq)$.

Differentiation with respect to p yields:

$$\frac{\partial z}{\partial p} = \pi q(1-\beta q)/c > 0 \tag{5}$$

and

$$\frac{\partial^2 z}{\partial p \partial q} = \frac{\pi}{c}(1 - 2\beta q). \tag{6}$$

Equation (5) shows that product market competition, measured by p, has a positive effect on innovation incentives: this is the "escape competition" or "escape entry" effect pointed out, for example, in Aghion et al. (2005) and Aghion et al. (2009). According to equation (6), patent protection, measured by q, affects the magnitude of the escape competition effect in two counteracting ways: (a) for given effective entry threat $p(1-\beta q)$, it increases the gain from escaping competition through innovation; and (b) it reduces the effective entry threat and therefore the incumbent firms' incentives to innovate in order to escape competition. The former effect dominates for low values of q, and for all values of q if β is small enough to fulfill $\beta < 1/2q$.

Overall, the model predicts that product market competition, and, thus, policy reforms that increase product market competition, have a positive effect on innovation incentives, and all the more so when patent protection is stronger. The latter holds, in particular, if the marginal effect of patent protection on the probability of entry (β) is sufficiently small.[12]

3 Empirical model

Our empirical model is designed to identify heterogeneity in the effect of a competition-increasing product market reform on innovation, depending on the strength of patent rights. The product market reform that we focus on consists of the substantial policy prescriptions that were part of the European Single Market Program in 1992. The reform was designed by the European Commission, a supranational institution, to enhance competition, innovation and economic growth. The effects of the reform were ex ante expected to vary across industries, as well as across countries, and the reform was repeatedly reported to reduce mark-ups and to increase product market competition (see Section 4 and Appendix B for details).

We proceed in two steps, using panel data for 13 industries in 17 European countries between 1987 and 2003. In the first step, we compare the effect of the product market

[12] We do not study the effects on consumer welfare, which are affected by both p and q, not only because they change the pace of innovation but also because they affect markups, since every time a patent is broken or entry is successful the markup falls in that industry from $\frac{1-\alpha}{\alpha}$ to zero. See Acemoglu and Akcigit (2012) for the welfare effects of a related model.

reform on innovation across two country groups: 1) countries with strong patent rights in the pre-sample period, 1980 to 1986, and throughout the sample period; 2) countries with weaker patent rights (see Section 4 and Appendix B for details). We estimate the following equation:

$$y_{ict} = \beta_1 R_{ict} * G(P^{strong}_{c,\ pre-sample\,(ps)}) + \beta_2 R_{ict} * G(P^{weak}_{c,\ ps}) + \gamma X_{ict} + \alpha_{ct} + \eta_{it} + u_{ict}, \quad (7)$$

where the explained variable y_{ict} measures innovation. Our main measure of innovation is R&D intensity, defined as R&D expenditures over value added. In addition, we use real R&D expenditures and a patent count. Countries are indexed by c, industries by i and time by t. The main explanatory variable R_{ict} is our measure of the product market reform. It is set to zero in all years before the implementation of the SMP. From 1992 onwards it takes values between zero and one, with a higher value indicating that ex ante experts were expecting the respective county-industry unit to be affected more by the SMP than other country-industries. We interact the reform measure with $G(P^{strong}_{c,\ pre-sample\,(ps)})$, a time-invariant indicator for the country group where patent rights P are strong since the pre-sample period, and also with $G(P^{weak}_{c,\ ps})$, the corresponding indicator for the country group with weaker patent rights. These indicators are constructed from information on patent law reforms and related regulation.

Country-year fixed effects, α_{ct}, are included to capture unobserved factors which may trigger country-specific changes of innovation over time. Industry-year fixed effects, η_{it}, are used to pick up factors inducing industry-specific trends over time. The vector X_{ict} captures further covariates, most importantly the pre-sample knowledge stock of country-industries to capture their initial innovative potential. The error term is denoted by u_{ict}. We cluster standard errors at the country-industry level to allow for unrestricted correlation between annual observations within the same country-industry.

Our main focus in equation (7) is on the coefficients of the two product market reform terms, β_1 and β_2. If stronger patent rights are to reinforce the positive effect of a competition-increasing product market reform on innovation, then the estimate of β_1 should be positive and larger than that of β_2. In our preferred model variant, the coefficients β_1 and β_2 are identified from data variation across time within country-industries and across country-industries.[13]

In the second step of our empirical analysis, we address the concern that the estimates of β_1 and β_2, and the extent to which these differ *across the country groups*, might be influenced by interactions of the product market reform with other factors, besides the country-specific patent protection regime. Similar as Sakakibara and Branstetter (2001) and Branstetter et al. (2006), we investigate whether the response of innovation to the product market reform varies *across industries*. We distinguish between industries where, in general and for exogenous technological reasons, innovators tend to rely strongly on patenting and, thus, should value strong patent protection highly, and other industries. In line with our main theoretical prediction, innovation in the former group of industries in countries with strong patent rights should respond more positively to a competition-increasing reform than in the other group of industries. We refer to these industries as industries with higher patent relevance. To identify them, we use the proxy $I_{i,\, ps}$ which indicates for each industry i the level of the patent intensity in the corresponding US industry in the pre-sample period 1980 to 1986.

We consider the following estimation equation:

$$\begin{aligned} y_{ict} = {} & \beta_{11} R_{ict} * G(P_{c,\, ps}^{strong}, I_{i,\, ps}^{>median}) + \beta_{12} R_{ict} * G(P_{c,\, ps}^{strong}, I_{i,\, ps}^{\leq median}) \\ & + \beta_{21} R_{ict} * G(P_{c,\, ps}^{weak}, I_{i,\, ps}^{>median}) + \beta_{22} R_{ict} * G(P_{c,\, ps}^{weak}, I_{i,\, ps}^{\leq median}) \\ & + \gamma X_{ict} + \delta G_{ic} + \alpha_{ct} + \eta_{it} + u_{ict}, \end{aligned} \tag{8}$$

where we estimate the innovation response to the product market reform separately for four country-industry groups. The dummy variable $G(P_{c,\, ps}^{strong}, I_{i,\, ps}^{>median})$ indicates the group of industries with high patent relevance in countries with strong patent rights. This group

[13] Our empirical findings are robust to identifying the effects from several alternative sources of data variation. We can, for example, vary the set of fixed effects (see Section 5). In addition, we find stable results when using alternative measures of the product market reform and of patent rights, and when using an instrumental variable approach.

covers the industries where innovators rely more on patenting, and where therefore patent protection should be more relevant, compared to the industry with median patent relevance. The dummy variable $G(P^{strong}_{c,\,ps}, I^{\leq median}_{i,\,ps})$ indicates the complementing group in countries with strong patent rights, covering the industries with low patent relevance in these countries. For countries with weaker patent rights we proceed analogously, constructing the indicators $G(P^{weak}_{c,\,ps}, I^{>median}_{i,\,ps})$ and $G(P^{weak}_{c,\,ps}, I^{\leq median}_{i,\,ps})$. To control for fixed country-industry group effects we include the vector of the group indicators, G_{ic}.[14]

The coefficients of main interest in equation (8) are β_{11} and β_{12}. If stronger patent rights are to enhance the positive effect of a competition-increasing product market reform on innovation, and the more so in industries where patent protection is more relevant, then the estimate of β_{11} should be positive and larger than that of β_{12}. In addition, the coefficient estimates for countries with strong patent rights, β_{11} and β_{12}, should be larger than the corresponding estimates for countries with weaker patent rights, β_{21} and β_{22}, and the difference $\beta_{11} - \beta_{12}$ should be larger than $\beta_{21} - \beta_{22}$.

In the final part of our empirical analysis, we extend our model specification to allow for interactions of the product market reform with country- and industry-specific financial factors, as well as with the initial knowledge stock of country-industries.

4 Data

For our main sample we use panel data for 13 industries in 17 European countries between 1987 and 2003.[15] The majority of countries, 11 out of the 17 countries for which we have the relevant data, were EU member states in 1992 and participated in the European Single Market Program, as shown in Table 1.[16] The other six European countries include Finland and Sweden that joined the EU in 1995. Among the 13 industries are nine two-digit industries

[14] The results for the model specification in equation (8) are provided in Section 5.2, along with the results for a specification where we allow the reform effect to vary more flexibly along the distribution of $I_{i,\,ps}$.

[15] In this section, we briefly introduce our data sources and main variables. Descriptive statistics are provided in Appendix Table A-1.

[16] For the twelfth EU member state in 1992, Luxembourg, data on R&D expenditures are missing.

and four more aggregate industries, all in manufacturing (see Table 2).[17] In section 5.3, we also use alternative samples which include the United States (US) or service industries.

Innovation

Our main measure of innovation is R&D intensity, defined as nominal R&D expenditures over nominal value added. To construct this variable, we use country-industry-year level data on research and development expenditures for the business enterprise sector from the 2011-version of the OECD ANBERD database and data on value added from the 2008-version of the EU KLEMS database (see also Appendix B.1). The second measure of innovation is real R&D expenditures, that is R&D expenditures at year 2000 prices converted to US dollars using purchasing power parity rates. The third measure is a count of patents taken out per country-industry-year in the US Patent and Trademark Office. The patent count data that we use are part of the EU KLEMS 2008 database and these are constructed from the NBER patent database with patents granted by the US Patent and Trademark Office (see also Appendix B.2 and Hall, Jaffe and Trajtenberg, 2001). Using data on US patents is advantageous in our context as low-value inventions are less likely to be patented abroad.

To capture the initial innovation potential of country-industries, we use a continuous measure of a patent-based knowledge stock built up until 1986, the end of the pre-sample period.

Patent rights

To capture the strength of patent rights we separate between countries with strong patent rights and those with weaker patent rights, based on information on patent law reforms and related regulation (see also Appendix B.3). One group of countries in our dataset had strong patent protection regimes already during the pre-sample period until 1986 and maintained strong regimes throughout the whole sample period, 1987 to 2003. The group covers seven out of the 11 countries in our sample that implemented the SMP, namely Belgium, Denmark, France, Germany, Italy, Netherlands, and the United Kingdom, and outside the area of the

[17] We grouped up to four two-digit industries together if the underlying raw data required us to do so. Industries are classified according to the European NACE classification (version 1993, revision 1).

SMP it covers Sweden (plus the United States). All other sampled countries form the group of countries with weaker patent protection regimes. This group includes four SMP countries, namely Greece, Ireland, Portugal, and Spain, as well as five non-SMP countries, namely the Czech and Slovak Republics, Finland, Hungary, and Poland.

All European countries in our group with strong patent rights, except for Denmark, were among those states that set up the European Patent Organisation (EPOrg) in October 1977.[18] The countries in our group with weaker patent rights joined the EPOrg between October 1986 and March 2004 (EPOrg, 2012) and none of these countries completed the required reforms for a strong patent protection regime before 1992 (Branstetter et al. 2006, Qian 2007, and World Intellectual Property Organization 2012, among others). Our classification is consistent with those used in Branstetter et al. (2006), Maskus and Penubarti (1995) and Qian (2007). In addition, we compare our patent protection measure to the index of patent protection that was developed by Ginarte and Park (1997) and updated by Park (2008). The index is updated every five years between 1960 and 2005, it takes country-specific values between zero and five, with higher values indicating patent laws with stronger IPR. In 1985, the countries in our group with strong patent rights have an index value of about 3.5 or more, the average index value being 3.9.[19] In 2000, their index values are at least 4.5. All countries in the group with weaker patent rights have a much lower index value (below 2.8) in 1985, except for Finland or countries with missing index data for that year. The average index value for 1985 is 2.5. In 2000 only two countries in that group, Ireland and Finland, scored above 4.5.

In the second part of our empirical analysis, when estimating the innovation response to the product market reform separately for four country-industry groups, we use the fol-

[18] The EPOrg is the intergovernmental organization that was created for granting patents in Europe under the European Patent Convention of 1973; the European Patent Office (EPO) acts as the executive body for the EPOrg and the first patent applications were filed in 1978. A European patent is a set of essentially independent patents with national enforcement, national revocation, and central revocation or narrowing as a group via two alternative unified, post-grant procedures.

[19] Columns 3 to 6 in Table 1 indicate the Ginarte-Park index values for the sampled countries in 1985, 1990, 1995 and 2000.

lowing industry grouping. First, we single out the industries with high patent relevance where, in general, innovators tend to rely more on patenting, and where therefore patent protection should be more relevant, compared to an industry with median patent relevance. Our preferred proxy for patent relevance, $I_{i,\,ps}$, ranks each industry i according to the patent intensity in the corresponding US industry in the pre-sample period, 1980 to 1986.[20] Second, we form the complementing industry group with low patent relevance. In a more flexible model specification, we consider three industry groups, respectively with low, medium and high patent relevance. Column 3 of Table 2 provides for each sampled industry information on the patent intensity in the corresponding US industry in 1983, and column 4 summarizes the ranking with three industry groups based on the US patent intensity data for the whole pre-sample period.

Product market reform

The product market reform that we focus on was part of the SMP implemented in 1992, a time with significant variation in patent protection across European Countries. Designed by the European Commission and therefore at a supra-national level, the SMP aimed at bringing down barriers to the free movement of products and production factors within the EU in order to foster competition, innovation and economic growth. Main components of the SMP include changes to national legislation meant to harmonize technical product standards within the EU; to simplify the physical movements of goods, labor, and other production factors across borders; and to reduce public sector discrimination in favor of national firms, for example due to mandatory international tendering for high-value procurement. Several empirical studies support the view that product market competition has increased in response to the SMP reform (Badinger 2007, Bottasso and Sembenelli 2001 and Griffith et al. 2010, among others).

The SMP was officially implemented in all sampled countries that had joined the EU before 1992. For these SMP countries, the European Commission report by Buigues, Ilzkovitz

[20] Using data on U.S. industries is advantageous here as the U.S. is the technology leader in most industries and it is not included in our main sample. See Appendix B.3 for details.

and Lebrun (1990) provides a common list of 40 three-digit manufacturing industries that were ex ante expected to be affected by the product market reform. Additions to and removals from the common list are also reported for each sampled country. These additions and removals reflect recommendations of experts, who were asked whether they expected the reform to change the product market conditions in an individual industry in a specific country differently than in the corresponding average industry in SMP countries. The reform measures that can be derived from the information in Buigues et al. (1990) vary across SMP countries, industries and time; a fact which we exploit to identify the reform impact from confounding influences. Further data variation is available as our main data set covers also non-SMP countries, not only SMP countries.

To construct our main measure of the product market reform we aggregate the information in Buigues et al. (1990) into a measure which is set equal to zero in all years before the implementation of the SMP. From 1992 onwards it is equal to the share of the three-digit classes in a two-digit industry of a SMP country that were ex ante expected to be affected by the SMP.[21]

In column 4 of Table 2, we show the product market reform intensity in 1992 for all 13 industries in our data set, averaged across the 11 sampled SMP countries. The industries that were expected to be affected least are 'coke, refined petroleum, and nuclear fuel', 'basic metals', and 'food, beverages, and tobacco'. Those that were expected to be affected most are 'motor vehicles, trailers, and semi-trailers', 'electrical and optical equipment', 'chemicals including pharmaceuticals', and 'general and special purpose machinery n.e.c., engines, turbines & domestic appliances n.e.c., machine tools, weapons'.

Financial variables

The financial variables which we use in section 5.3 are explained in that section and in Appendix B.5.

[21] Note that the industry ranking based on our main SMP measure corresponds to the ranking based on the SMP measure of Griffith et al. (2010) for all industries in our data set, up to two deviations. Griffith et al. (2010) constructed their SMP measure differently than we do due to different data availability. See Appendix B.4 for details.

5 Empirical results

5.1 Baseline results

We start by separately estimating the average effect of the competition-increasing product market reform which is part of the European Single Market Program and the average effect of patent protection on innovation. This prepares the ground for analyzing effects of the interaction between the two factors on innovation. We report OLS estimation results in Table 3 for the main sample, an unbalanced panel of 2,761 observations for 13 manufacturing industries in 17 European countries between 1987 and 2003. All model specifications include country, industry and year indicators to capture country, industry and year effects. Standard errors are robust and clustered on the country-industry level to allow for unrestricted correlation between annual observations within the same country-industry.

Our first finding is that of a positive average effect of the product market reform intensity on R&D intensity in column 1 of Table 3.[22] The coefficient estimate indicates that enhancing the reform intensity by one standard deviation (0.3076) increases R&D intensity by 0.0108 (=0.0352*0.3076).[23] This represents about 23 percent of the mean value of R&D intensity (0.0464), a reasonable effect size. Such an average effect estimate is consistent with the theoretical prediction of an escape competition effect, as discussed in Section 2. In addition, it fits with the empirical results of Griffith et al. (2010).[24]

Our second finding is that there does not seem to be any positive (or negative) significant average effect of patent protection on R&D intensity. In column 2, we show the coefficient estimate on a time-varying indicator which equals one in case of strong patent rights, and zero otherwise. The estimate is small, positive and not significantly different from zero.[25] This is consistent with previous empirical evidence, in particular by Sakakibara and Branstetter

[22] See Section 4 for the definitions of the variables.

[23] See Appendix Table A-1 for descriptive statistics on the reform intensity.

[24] Griffith et al. (2010) use data on a similar set of industries in a different set of countries (Belgium, Canada, Denmark, Finland, France, Netherlands, United Kingdom and the United States) and a different, although related, measure of the SMP product market reform.

[25] Using the time-varying patent protection index provided by Ginarte and Park (1997) and Park (2008) yields a very similar coefficient estimate. The result is available upon request.

(2001) for the manufacturing sector in Japan or by Qian (2007) for the pharmaceutical industry in OECD countries.

These two findings are robust to including both terms on the right hand side of the estimation equation, the linear term for the competition-increasing product market reform and the linear term for patent protection (see column 3).

5.2 Main results

Our main interest in this paper is the response of innovation to the interplay between the strength of patent rights and the competition-enhancing product market reform. As shown in Figure 1, our raw data directly hints at heterogeneity in the response to the reform, depending on patent protection. The left-hand graph refers to countries with strong patent rights since the pre-sample period, the right-hand graph refers to countries with weaker patent rights. The vertical axes indicate R&D intensity, the horizontal axes indicate the SMP reform intensity. Circles represent the country-industry-year data points between the fifth and the ninety-fifth percentile of the R&D intensity distribution in the sample. The regression line for countries with strong patent rights has a more positive slope than the corresponding line for countries with weaker patent rights.[26] Overall, the raw data pattern is consistent with the view that innovation responds more strongly to the competition-enhancing reform if patent rights are stronger.

Next, we estimate equation (7) of Section 3. The estimation results in Table 4 indicate a positive effect of the product market reform intensity on R&D intensity for countries with strong patent rights. For countries with weaker patent rights we find no such effect. These findings are stable across the following four variants of the empirical model: a) the model variant in column 1 of Table 4, where we control for country, industry, and year fixed effects; b) the one with the interaction term *Product market reforms* (R_{cit})$*$ *G(Protection* $(P)_c^{strong}$) and the level term R_{cit} in which the coefficient on the former indicates how the reform effect

[26] Each of these regression lines indicates the linear predictions from a country group-specific linear regression of R&D intensity on the product market reform intensity as the sole explanatory variable.

for the country group with strong patent rights deviates from the reform effect for the group with weaker patent rights (column 2); c) the one with time-varying country effects and time-varying industry effects (column 3); d) and, finally, the model variant with the knowledge stock in country-industries in 1986 as explanatory variable (column 4).

Our findings are also robust to several changes in the way we measure our main explanatory variables. We can, for example, replace our pre-sample measure of patent protection by the Ginarte-Park index $(Protection_{ct}^{GP})$. Column 5 of Table 4 provides the respective OLS estimates and column 6 the second stage estimates of a 2SLS regression. We implement an instrumental variable approach as the contemporaneous Ginarte-Park index may reflect regulatory changes that are endogenous to innovation during our sample period. As excluded instrument, we use the interaction of the country-specific pre-sample indicator of strong patent rights and the product market reform intensity.[27] The second stage estimates on the two product market reform terms indicate that the reform effect on R&D intensity increases with the strength of patent rights and is positive for index values above 3.7. About 65% of all sample observations in 1992 have higher index values than 3.7 and in later years the percentage is even higher.[28]

All our estimation results in Table 4 suggest a complementarity between the competition-enhancing product market reform and the strength of patent rights, in line with our theoretical prediction in Section 2. A potential concern with these results is that the coefficient estimates on the product market reform terms for countries with strong patent rights, and their deviation from those for countries with weaker patent rights, could be driven by reform interactions with factors other than the country-specific patent protection regime.

To address this concern, we investigate how the positive effect of the product market reform on R&D intensity which is *specific to countries* with strong patent rights *varies*

[27] The coefficient estimate *(s.e.)* on the excluded instrument in the first stage equation is 0.7336*** *(0.1254)*. The test statistic for the F-test on the irrelevance of the excluded instrument takes a value of 34.24 and we reject the null hypothesis.

[28] The weak identification test result at the bottom of column 6 indicates that the null hypothesis of the 2SLS bias exceeding 10 percent of the OLS bias can be rejected (see also Stock and Yogo, 2005).

across industries. As argued in Section 3, we expect the interaction between the reform intensity and the strength of patent rights to be stronger in industries where innovators rely more on patenting and where, therefore, patent protection should be valued more than in other industries. We refer to these industries as industries with higher patent relevance and proxy patent relevance in industry i with the patent intensity in the corresponding US industry during the pre-sample period 1980 to 1986.[29]

Column 1 of Table 5 provides the estimation results for the model specification of equation (8), allowing for different innovation responses to the competition-increasing product market reform in four country-industry groups. The first group covers the industries with above median patent relevance in countries with strong patent rights, denoted by $G(P_{c,\,ps}^{strong}, I_{i,\,ps}^{>median})$ and the second group covers the industries with lower patent relevance in these countries, indicated by $G(P_{c,\,ps}^{strong}, I_{i,\,ps}^{\leq median})$. For countries with weaker patent rights, two corresponding groups are considered. We find positive effects of the competition-increasing product market reform on R&D intensity in both industry groups for countries with strong patent rights. More importantly, we find a higher reform effect for industries with above median patent relevance than in the complementing group of industries.[30] For countries with weaker patent rights, we find small and non-significant reform effect estimates that do not differ between the two industry groups.[31] Replacing these two terms with the level term of the product market reform measure R_{cit} in column 2, we find consistent evidence.[32]

In column 3, we consider a model specification which allows for differential reform effects on R&D intensity across three industry groups in countries with strong patent rights, respectively with high, medium and low patent relevance. For countries with weaker patent

[29] Recall our discussion in Sections 3 and 4 and see the Data Appendix.

[30] The F-test statistic for the test of the null hypothesis "N_0: $\beta_{11} - \beta_{12} = 0$" is 4.02 (p-value: 0.0462). In addition, we find that the effect estimates for countries with strong patent rights differed significantly more than those for countries with weaker patent rights. The corresponding F-test statistic for the test of the null hypothesis "N_0: $(\beta_{11} - \beta_{12}) - (\beta_{21} - \beta_{22}) = 0$" is 3.10 (p-value: 0.0796).

[31] The F-test statistic for the null hypothesis "N_0: $\beta_{21} - \beta_{22} = 0$" is 0.22 (p-value: 0.6402).

[32] The reform effect estimates for both industry groups in countries with strong patent rights are significantly higher than the estimate of the coefficient on the R_{cit}-term which reflects the reform effect for countries with weaker patent rights. The latter estimate deviates most from the estimate for the industry group with patent relevance above the median in countries with strong patent rights.

rights, we estimate the average effect of the product market reform.[33] We find further support for complementarity between the competition-increasing product market reform and the strength of patent rights: R&D intensity responds more strongly to the product market reform in country-industries where patent rights are strong and where patent relevance takes medium or high values, rather than low values.

More precisely, we observe for countries with strong patent rights that the response is stronger in industries with an intermediate level of patent relevance than in those with high or low levels.[34] That the complementarity between the competition-increasing product market reform and the strength of patent rights weakens in our group of industries with highest patent relevance values is in line with our theoretical argument if this group covers industries where the scope for entry deterrence through patenting is large enough. In such industries the marginal deterrence parameter β in Section 2 takes high values, indicating that entry can be (partly) deterred through patent thickets, dense webs of overlapping patent rights caused by strategic patenting and technological conditions.[35] Support for the view that our industries with high patent relevance are industries where patent thickets are most likely to be prevalent and that, therefore, β-values are likely to be high follows, for example, from the work of von Graevenitz, Wagner and Harhoff (2011a, 2011b). All the technologies for which their measure of patent thicket density takes high values can be linked to our group of industries with highest patent relevance values: audiovisual technology, telecommunications, semiconductors, information technology, optics, electrical machinery and electrical energy,

[33] The average effect estimate in column 3 turns out to be small and insignificant. In column 4, allowing for effect variation across three industry groups in countries with weaker patent rights leads to small, insignificant effect estimates for all three groups, and these are not significantly different from each other.

[34] F-test results indicate that the reform effect estimates for the industry groups with intermediate and low patent relevance differ significantly (p-value: 0.0102), but those for the groups with high and low patent relevance fail to differ at the 10%-significance level (p-value: 0.1272). Further support for the non-linear pattern follows from the extensions to the main empirical analysis in section 5.3 (see column 3 in Table 6, columns 2 and 4 in Table 7, and panel B in Table A-2).

[35] Empirical evidence on the effect of patent thickets on firm entry is scarce. Hall, Helmers, von Graevenitz and Rosazza-Bondibene (2012), however, show that the density of a patent thicket in a technology area is associated with reduced entry into patenting in that technology area, using data on patenting firm entities with at least one patent application at the IPO in the UK or at the EPO during the years 2001to 2009.

engines, pumps and turbines.[36]

Overall, the above results provide compelling evidence of a complementarity between the strength of patent rights and the competition-enhancing product market reform. First, we find a positive average reform effect on R&D intensity in industries of countries with strong patent rights, not in industries of countries with weak patent rights. Second, we observe that the complementarity is more pronounced in industries where innovators rely more on patenting than in other industries, and where the scope for deterring entry through patenting is not too large.

5.3 Extensions

In addition to R&D intensity, we also explain alternative measures of innovation. First, we consider real R&D expenditures in order to show that our previous findings do not simply reflect value added responding to product market reforms (Table 6, columns 1, 2 and 3).[37] Second, we use a patent count (Table 6, columns 4, 5 and 6).[38] We find a positive effect of the competition-increasing product market reform on real R&D expenditures, as well as on the number of patents, in countries with strong patent rights since the pre-sample period (Table 6, columns 1 and 4). These results are in line with the findings for the R&D intensity models in Table 4. In addition, the positive innovation response to the product market reform in countries with strong patent rights is more pronounced in industries with medium or high rather than low patent relevance (Table 6, columns 2, 3, 5 and 6). In the model with real R&D expenditures in column 3 of Table 5 we find a similarly non-monotonic pattern of

[36] Von Graevenitz et al. (2011a, 2011b) measure the density of a patent thicket with a count of blocking relationships identified from patent citations, specifically X and Y references in search reports of the European Patent Office. Type X or Y references refer to prior art documents, which call the novelty or the inventive step of a patent claim into question. A blocking relationship is defined as a set of patent links where three firms mutually block each other according to X or Y references, called a triple. The technologies that we list in the main text represent all those with high mean triple values, i.e. values between 18.53 and 93.68 in Table 1 of von Graevenitz et al. (2011a). See also Hall (2005).

[37] The results for the real R&D expenditures model are robust to including a control for real value added, that is, value added at constant prices in 2000 in US dollar purchasing power parities.

[38] The patent count model is estimated on a smaller sample with a shorter time horizon, namely the period for which patent data are available to us (1987 to 1999). We estimate a linear probability model where including country-year fixed effects and industry-year fixed effects is straightforward (Wooldridge, 2010).

reform effect estimates as for the R&D intensity models of columns 3 and 4 of Table 4.

A lingering concern with our estimation results so far, is that these might be driven by a different mechanism causing similar heterogeneity in reform effects across countries, as well as across industries. In particular, if firms need to borrow to finance their innovative investments, a competition-enhancing product market reform may increase innovation more in countries with more developed financial sectors than in other countries. And the impact of financial sector development should be disproportionately larger in industries where firms typically rely more on external finance than in other industries.

To address this concern, we add further covariates to our set of explanatory variables, namely interaction terms of the product market reform intensity with the relevant financial variables. To measure financial sector development at the country-level, we use a private credit ratio from the November 2010 version of the Financial Development and Structure Database by Beck, Demirgüc-Kunt and Levine (2000, 2010b). The ratio is defined as the claims of deposit money banks and other financial institutions on the private sector, relative to gross domestic product (GDP).[39] It is available for all sampled countries, excluding the Czech Republic and the Slovak Republic, for at least four pre-sample years between 1980 and 1986. To construct the required pre-sample indicator of high financial sector development we proceed as follows: we average all pre-sample ratio values per country and classify the countries with averages at or above the 75 percentile of the sample distribution as having a highly developed financial sector. These countries are France, Germany, the Netherlands and Sweden.[40] To distinguish between industries according to their reliance on external finance, we follow Rajan and Zingales (1998) and use industry-level data on the share of capital expenditures firms cannot finance internally: the ratio of firms' capital expenditures minus cash flow from operations, divided by capital expenditures. Rajan and Zingales (1998) provide those data for US industries during the 1980s. We link the industries in our sample

[39] See Appendix B for further details.

[40] We also construct an alternative measure involving the median as a cut-off point and a measure based on stock market capitalization relative to GDP. Reestimating the model of column 1 in Table 7 with these alternative measures, we find support for the main results reported below.

to the corresponding US industries and distinguish three industry groups: the group with low reliance on external finance covers the industries with ratios below the 25th percentile of the sample distribution, the group with high reliance on external finance covers the industries with ratios above the 75th percentile, and the remaining industries form the intermediate group.

Column 1 of Table 7 provides the estimates for a model specification which adds the following interaction term to the specification of column 4 in Table 4: the interaction between the product market reform intensity and the indicator for countries with highly developed financial sectors, $R_{cit} * G(Financial\ development\ (FD)^{high}_{c,\ ps})$. In line with our previous findings, the response of R&D intensity to the competition-increasing product market reform is stronger in countries with strong patent rights than in countries with weaker patent rights. Moreover, the coefficient estimate on the reform term specific to countries with high financial sector development is positive and statistically significant.

Column 2 of Table 7 provides the estimates for the model specification which adds three interaction terms to the specification of column 4 in Table 5: the interaction between the product market reform intensity and the indicator for industries with high reliance on external finance in countries with highly developed financial sectors, $R_{cit} * G(FD^{high}_{i,\ ps}, External\ finance\ (E)^{high}_{i,\ ps})$, and the two complementing interactions, namely $R_{cit} * G(FD^{high}_{i,\ ps}, E^{medium}_{i,\ ps})$ and $R_{cit} * G(FD^{high}_{i,\ ps}, E^{low}_{i,\ ps})$. Again, our main findings hold up: in countries with strong patent rights, R&D intensity responds more strongly to the competition-enhancing product market reform in industries with medium or high patent relevance than in industries with low patent relevance and the response is most pronounced in industries with medium patent relevance.[41] In addition, we find that high financial sector development enhances the innovation response to the product market reform more the stronger an industry's firms rely on external finance.

The innovation response to the competition-enhancing product market reform may also

[41] The coefficient estimate on the reform term for industries with intermediate patent relevance is largest and statistically significant. Second comes the one for industries with high patent relevance and third the one for industries with low patent relevance, but both these estimates fails to pass the 10%-significance level.

depend upon initial conditions of country-industries. To capture this, we proceed as follows. We interact the product market reform intensity with an indicator for those country-industries that are at or above the median of the sample distribution of our knowledge stock measure.[42] We then add the new interaction term, denoted by $R_{cit} * G(Knowledge\ stock^{high}_{ci,\,1986})$, to the model specification of column 4 in Table 4. The respective coefficient estimate turns out to be positive, but remains insignificant with a p-value of 0.1717 (Table 7, column 3). Most importantly, allowing for the additional interaction does not challenge our main finding of R&D intensity responding more strongly to the reform in countries with strong patent rights. In column 4 of Table 7 we augment the model specification of column 4 in Table 5 with the same interaction term, $R_{cit} * G(Knowledge\ stock^{high}_{ci,\,1986})$. The empirical results then confirm that the innovation response to the competition-increasing product market reform is strongest in the country-industry group with strong patent rights and intermediate patent relevance.

Finally, we modify the data variation that we use for identifying the product market reform effects on innovation. Our main identification strategy involves using data variation *within* 11 countries that fell under the SMP product market reform, as well as variation *between* these SMP countries and six other countries. If we reduce the variation by using data for the 11 SMP countries only, our main results turn out to be stable (see Table A-2 in the Appendix, column 1, panels A and B). When extending the sample by adding the US, a large non-European country with high innovative potential, we also find support for our main results (Table A-2, column 2). Our empirical findings remain robust as well if we reestimate on a much larger sample with 8 service industries, in addition to the 13 manufacturing industries in our main sample (Table A-2, column 3).[43] Finally, the main findings are also stable when reestimating on the 47 samples that result if we exclude individual industries, countries or years one by one.

[42]Note that the estimation results are similar if we use the 75th percentile as cut-off point.

[43]Note that our product market reform measure is always equal to zero in service industries.

6 Conclusions

In this paper, we contributed empirical evidence suggesting that strong patent rights can complement competition-increasing product market reforms in inducing innovation. Our main findings are as follows. First, the product market reform that was part of the European Single Market Program in 1992 enhances innovation in industries that are located in countries where patent rights are strong, but not in industries of countries where patent rights are weak. Second, the positive innovation response to the product market reform is more pronounced in industries in which innovators rely more on patenting than in other industries, and in which the scope for deterring entry through patenting is not too large.

These empirical findings are in line with the predictions of growth models with step-by-step innovation in which product market competition encourages firms to innovate in order to escape competition. In such a model, patent protection and product market competition can act as complementary engines of innovation, rather than as counteracting forces. The complementarity arises as product market competition typically lowers the pre-innovation rent, possibly also the post-innovation rent, but may enlarge the net innovation rent, and the more so the stronger patent rights protect the post-innovation rent.

Our analysis has implications for the long-standing policy debate on the need for and the design of patent systems. Complementarity of patent protection with competition in product markets, as well as with competition-enhancing product market interventions, need to be taken into account when assessing the effects of patent policies. More generally, our work provides support for the importance of interaction effects between different types of institutions and policies in the growth process.

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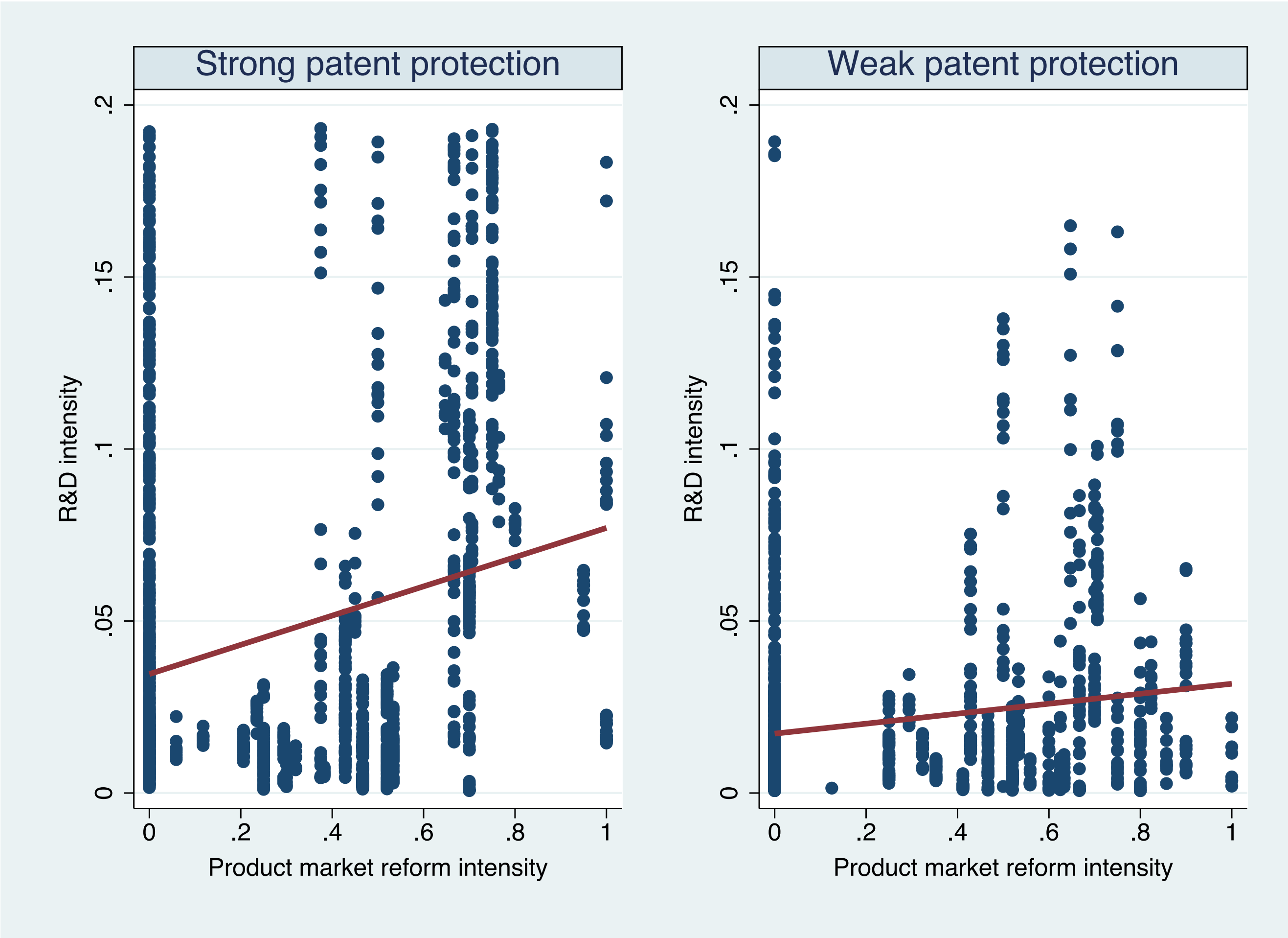
Figures and Tables

Figure 1: Patent rights, product market reforms and innovation
- A first look at the raw data -



Notes: In this figure we show the relation between product market reforms and innovation in countries with strong patent protection during the pre-sample period (left graph) and in countries with weaker patent protection (right graph). The horizontal axes refer to our measure of product market reform intensity, the vertical axes to R&D intensity and the circles indicate all country-industry-year data points between the fifth and the ninety-fifth percentile of the R&D intensity distribution in our raw data for the sample period 1987 to 2003. The lines represent linear predictions of R&D intensity from country group-specific linear regressions of R&D intensity on product market reform intensity as the sole explanatory variable.

Table 1: Patent protection per country

	Adoption of strong patent protection	Patent protection index			
		1985	1990	1995	2000
EU member states with SMP reform in 1992					
Belgium (BEL)	early	4.0917	4.3417	4.5417	4.6667
Denmark (DNK)	early	3.6333	3.8833	4.5417	4.6667
France (FRA)	early	3.7583	3.8833	4.5417	4.6667
Germany (GER)	early	3.8417	3.9667	4.1667	4.5000
Greece (GRC)	late	2.3250	2.8667	3.4667	3.9667
Ireland (IRL)	late	2.2000	2.3250	4.1417	4.6667
Italy (ITA)	early	3.6833	4.0083	4.3333	4.6667
Netherlands (NLD)	early	3.7667	4.2167	4.5417	4.6667
Portugal (PRT)	late	1.6657	1.6657	3.3490	4.0050
Spain (ESP)	late	2.8080	3.5583	4.2083	4.3333
United Kingdom (UK)	early	3.8833	4.3417	4.5417	4.5417
European countries outside EU until 1995					
Finland (FIN)	late	3.3083	3.3083	4.4167	4.5417
Sweden (SWE)	early	3.4833	3.8833	4.4167	4.5417
European countries outside EU until 2003					
Czech Republic (CZE)	late	n.a.	n.a.	2.9583	3.2083
Hungary (HUN)	late	n.a.	n.a.	4.0417	4.0417
Poland (POL)	late	n.a.	n.a.	3.4583	3.9167
Slovak Republic (SVK)	late	n.a.	n.a.	2.9583	2.7583
Non-European countries (not in main estimation sample)					
United States (US)	early	4.6750	4.6750	4.8750	4.8750

Notes: In column 2 we indicate whether a sampled country adopted strong patent protection early or late in time, distinguishing between countries that fell under the product market reforms of the EU Single Market Program (SMP) and those that didn't. Countries with strong patent rights in the pre-sample period and throughout the sample period are classified as early adopters. Countries with weaker patent rights are late adopters, completing their reforms relevant to a strong patent protection regime in 1992, or even later. For comparison, columns 3 to 6 provide information on the patent protection index by Park (2008) and Ginarte and Park (1997); it takes values between zero and five and higher values indicate stronger patent protection. The term 'n.a.' indicates a missing index value.

Table 2: Patent relevance and product market reform per industry

	Industry	US patent intensity share	US patent intensity rank (group)	Product market reform share (s.e.)
15-16:	food, beverages, and tobacco	0.0040	1 (low)	0.3075 (0.1201)
17-19:	textiles, leather, and footwear	0.0053	2 (low)	0.5727 (0.1281)
23:	coke, refined petroleum, and nuclear fuel	0.0276	6 (medium)	0.0000 (0.0000)
24:	chemicals including pharmaceuticals	0.0672	10 (medium)	0.7227 (0.1311)
25:	rubber and plastics	0.0604	9 (medium)	0.4675 (0.1292)
26:	other non-metallic mineral products	0.0287	7 (medium)	0.5455 (0.1623)
27:	basic metals	0.0117	3 (low)	0.0749 (0.1536)
28:	fabricated metal products	0.0533	8 (medium)	0.3409 (0.1776)
29:	general & special purpose machinery n.e.c., engines, turbines & domestic appliances n.e.c., machine tools, weapons	0.0904	11 (high)	0.7409 (0.1020)
30-33:	electrical and optical equipment incl. computing machinery, radio, television and (tele)communication equipment	0.0948	12 (high)	0.7112 (0.0489)
34:	motor vehicles, trailers, and semi-trailers	0.0182	5 (medium)	0.6970 (0.1798)
35:	other transport equipment	0.0150	4 (medium)	0.4659 (0.1590)
36-37:	furniture, jewelery, games & toys, musical instruments, sports goods, recycling	0.1238	13 (high)	0.4545 (0.0934)

Notes: In column 3 of this table we provide the industry-specific US patent intensity in 1983, and in column 4 the industry-specific patent relevance ranking based on the US patent intensity data for the pre-sample period, 1980 to 1986. In column 5 we show the product market reform intensity in 1992 in the sampled 13 two-digit industries, averaged across the 11 countries that fell under the product market reform of the SMP (see Table 1). The measure is defined as the share of three-digit classes per two-digit industries of SMP-countries that were ex ante expected to be affected by the reform. The measure is set to zero in all years before the implementation of the reform, from 1992 onwards it takes a positive value in country-industries that were ex ante expected to be affected, otherwise zero. Country-industries with higher values were expected to be affected more than others.

Table 3: Basic models explaining R&D intensity

	Dependent variable: R&D intensity$_{cit}$		
	OLS	OLS	OLS
	(1)	(2)	(3)
Explanatory Variables:			
Product market reforms$_{cit}$	0.0352***		0.0356***
	(0.0099)		(0.0099)
Patent protection$_{ct}$		0.0003	0.0027
		(0.0062)	(0.0061)
Country effects	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Observations	2,761	2,761	2,761

Notes: In this table we provide OLS estimates of basic models explaining R&D intensity in our main sample, an unbalanced panel of 2,761 observations on 13 manufacturing industries in 17 European countries between 1987 and 2003.
R&D intensity$_{cit}$ is defined as R&D expenditures over value added. The product market reform intensity, *Product market reforms*$_{cit}$, equals zero in all years before the implementation of the SMP, from 1992 onwards it takes positive values up to 1 with higher values for country-industries that were ex ante expected to be affected more by the SMP than others. The measure *Patent protection*$_{ct}$ is coded one as soon as a country completed its reforms preparing the ground for a strong patent protection regime, and zero otherwise. Standard errors in parentheses are robust and clustered to allow for unrestricted correlation between annual observations within country-industries. Statistical significance at the 1% level is indicated by ***.

Table 4: Main models explaining R&D intensity: Part 1

	Dependent variable: R&D intensity$_{cit}$					
	OLS	OLS	OLS	OLS	OLS	IV
Explanatory Variables:	(1)	(2)	(3)	(4)	(5)	(6)
Product market reforms $(R)_{cit}$	0.0525***	0.0451***	0.0870***	0.0885***		
*G(Protection $(P)^{strong}_{c,\ pre-sample\ (ps)}$)	(0.0115)	(0.0132)	(0.0229)	(0.0241)		
R_{cit}*G($P^{weak}_{c,\ ps}$)	0.0074					
	(0.0125)					
R_{cit}		0.0074	-0.0060	-0.0065	-0.1466**	-0.4467***
		(0.0125)	(0.0219)	(0.0220)	(0.0676)	(0.1437)
R_{cit}*Protection$^{GP}_{ct}$					0.0482***	0.1206***
					(0.0162)	(0.0344)
Knowledge stock$_{ci,1986}$				-0.0008	0.0008	-0.0002
				(0.0037)	(0.0037)	(0.0033)
Country-year effects	No	No	Yes	Yes	Yes	Yes
Industry-year effects	No	No	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	No	No	No	No
Industry effects	Yes	Yes	No	No	No	No
Year effects	Yes	Yes	No	No	No	No
Weak identification test: Kleibergen-Paap rk Wald F Statistic						34,236 [1]
Observations	2,761	2,761	2,761	2,761	2,761	2,761

Notes: In this table we provide OLS and IV estimates of R&D intensity models for our main sample, an unbalanced panel of 2,761 observations on 13 manufacturing industries in 17 European countries between 1987 and 2003.
R&D intensity$_{cit}$ is defined as R&D expenditures over value added. The product market reform measure R_{cit} equals zero in all years before the implementation of the SMP, from 1992 onwards it takes positive values up to 1 with higher values for country-industries that were ex ante expected to be affected more by the SMP than others. Country groups are indicated by G(·). The group G($P^{strong}_{c,\ pre-sample\ (ps)}$) covers the countries where patent protection P is strong in the pre-sample period and throughout the sample period. The group G($P^{weak}_{c,\ pre-sample\ (ps)}$) covers the countries with weaker patent protection.
The measure *Protection*$^{GP}_{ct}$ is the patent protection index of Ginarte and Park (1997) and Park (2008). In column 5, we exclude the instrument R_{cit}*G($P^{strong}_{c,\ ps}$). The number of first stage equations is given in brackets at the bottom of column 5.
The variable *Knowledge stock*$_{ci,1986}$ is the patent-based knowledge stock per country-industry in 1986.
Standard errors in parentheses are robust and clustered to allow for unrestricted correlation between annual observations within country-industries. Statistical significance at the 1% and 5% level is indicated by *** and **.

Table 5: Main models explaining R&D intensity: Part 2

	Dependent variable: R&D intensity$_{cit}$			
	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)
Explanatory Variables:				
Product market reforms $(R)_{cit}$	0.1163***	0.1205***		
*G(Protection $(P)^{strong}_{c,\,ps}$, Patent relevance $(I)^{>\,med.}_{i,\,ps}$)	(0.0274)	(0.0267)		
R_{cit}*G($P^{strong}_{c,\,ps}$, $I^{\leq\,median}_{i,\,pre-sample(ps)}$)	0.0591**	0.0682***		
	(0.0228)	(0.0250)		
R_{cit}*G($P^{weak}_{c,\,ps}$, $I^{>\,median}_{i,\,ps}$)	-0.0028			
	(0.0220)			
R_{cit}*G($P^{weak}_{c,\,ps}$, $I^{\leq\,median}_{i,\,ps}$)	-0.0140			
	(0.0265)			
R_{cit}*G($P^{strong}_{c,\,ps}$, $I^{high}_{i,\,ps}$)			0.0643**	0.0628*
			(0.0295)	(0.0343)
R_{cit}*G($P^{strong}_{c,\,ps}$, $I^{medium}_{i,\,ps}$)			0.0853***	0.0730***
			(0.0257)	(0.0262)
R_{cit}*G($P^{strong}_{c,\,ps}$, $I^{low}_{i,\,ps}$)			0.0184	0.0087
			(0.0237)	(0.0232)
R_{cit}*G($P^{weak}_{c,\,ps}$, $I^{high}_{i,\,ps}$)				0.0076
				(0.0301)
R_{cit}*G($P^{weak}_{c,\,ps}$, $I^{medium}_{i,\,ps}$)				-0.0167
				(0.0225)
R_{cit}*G($P^{weak}_{c,\,ps}$, $I^{low}_{i,\,ps}$)				-0.0102
				(0.0227)
R_{cit}		-0.0060	-0.0094	
		(0.0208)	(0.0211)	
Knowledge stock$_{ci,1986}$	-0.0022	-0.0022	-0.0025	-0.0026
	(0.0037)	(0.0038)	(0.0040)	(0.0040)
Controls for G(*)$_{ci}$-groups	Yes	Yes	Yes	Yes
Country-year effects	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes
Observations	2,761	2,761	2,761	2,761

Notes: In this table we provide OLS estimates of R&D intensity models for our main sample, also used in Table 4.
Country-industry groups are indicated by G(·). We divide the country-group with strong pre-sample patent protection, as well as the one with weaker protection, into industry-specific sub-groups based on the patent relevance in industry i, *Patent relevance* $(I)_{i,ps}$. Measure $I_{i,ps}$ reflects for each industry i the level of the patent intensity in the corresponding US industry in the pre-sample period, 1980 to 1986. The group with above median patent relevance covers the six industries that constitute in all pre-sample years the industries with the six highest patent intensities, and the other group complements. The group with high patent relevance covers the three sampled industries that constitute in all pre-sample years the industries with the three highest patent intensities. The group with low patent relevance covers the three industries that score lowest, and the remaining seven industries form the intermediate group.
All other variables are defined as in Table 4. Standard errors in parentheses are robust and clustered to allow for unrestricted correlation between annual observations within country-industries. Statistical significance at the 1%, 5% and 10% level is indicated by ***, ** and *.

Table 6: Models explaining alternative outcome variables

	Dependent variables:					
	Real R&D expenditures$_{cit}$			Patent count$_{cit}$		
	OLS	OLS	OLS	OLS	OLS	OLS
Explanatory Variables:	(1)	(2)	(3)	(4)	(5)	(6)
Product market reforms $(R)_{cit}$	0.9503**			0.0592*		
*G(Protection $(P)^{strong}_{c,\, pre-sample\ (ps)}$)	(0.4061)			(0.0320)		
R_{cit}*G($P^{strong}_{c,\, ps}$,		1.4065***			0.1245***	
Patent relevance $(I)^{\geq\, med.}_{i,\, ps}$)		(0.4411)			(0.0473)	
R_{cit}*G($P^{strong}_{c,\, ps}$, $I^{<\, median}_{i,\, ps}$)		1.0305**			0.0032	
	(0.4902)			(0.0208)		
R_{cit}*G($P^{strong}_{c,ps}$, $I^{high}_{i,ps}$)			0.7271*			0.0886
			(0.3905)			(0.0552)
R_{cit}*G($P^{strong}_{c,\, ps}$, $I^{medium}_{i,ps}$)			1.4546***			0.0637*
			(0.5137)			(0.0336)
R_{cit}*G($P^{strong}_{c,\, ps}$, $I^{low}_{i,ps}$)			0.2265			-0.0044
			(0.2551)			(0.0190)
R_{cit}	-0.1711	-0.2725	-0.1901	0.0048	0.0086	0.0021
	(0.3002)	(0.3033)	(0.3038)	(0.0245)	(0.0245)	(0.0245)
Knowledge stock$_{ci,1986}$	0.6337***	0.6587***	0.6761***	0.2711***	0.2671***	0.2703***
	(0.1370)	(0.1423)	(0.1405)	(0.0155)	(0.0163)	(0.0158)
Controls for G(*)$_{ci}$-groups	No	Yes	Yes	No	Yes	Yes
Country-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation period	87-03	87-03	87-03	87-99	87-99	87-99
Observations	2,761	2,761	2,761	2,031	2,031	2,031

Notes: In this table we provide OLS estimates of models explaining real R&D expenditures for our main sample, also used in Table 4. The OLS estimates of models explaining patent counts are for the sub-sample with all 2,031 observations for the years 1987 to 1999.
The variable *Real R&D expenditures*$_{cit}$ is defined as R&D expenditures at constant prices in 2000 converted to US dollars using purchasing power parity rates (in billion). The measure *Patent count*$_{cit}$ is a fractional count of patents taken out per country-industry-year in the US Patent Office.
All other variables are defined as in Tables 4 and 5. Standard errors in parentheses are robust and clustered to allow for unrestricted correlation between annual observations within country-industries. Statistical significance at the 1%, 5% and 10% level is indicated by ***, ** and *.

Table 7: Models accounting for alternative explanations

	Dependent variables: R&D intensity$_{cit}$			
	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)
Explanatory Variables:				
Product market reforms (R)$_{cit}$ *G(Financial development (FD)$^{high}_{c,\ ps}$)	0.0729**			
	(0.0368)			
R$_{cit}$*G(FD$^{high}_{c,\ ps}$, External finance (E)$^{high}_{i,\ ps}$)		0.0652**		
		(0.0384)		
R$_{cit}$*G(FD$^{high}_{c,\ ps}$, E$^{medium}_{i,\ ps}$)		0.0569		
		(0.0433)		
R$_{cit}$*G(FD$^{high}_{c,\ ps}$, E$^{low}_{i,\ ps}$)		0.0551		
		(0.0424)		
R$_{cit}$*G(Knowledge stock$^{high}_{ci,\ 1986}$)			0.0339	0.0252
			(0.0247)	(0.0260)
R$_{cit}$*G(Protection (P)$^{strong}_{c,\ pre-sample\ (ps)}$)	0.0589**		0.0667**	
	(0.0249)		(0.0292)	
R$_{cit}$*G(P$^{strong}_{c,ps}$, Patent relevance (I)$^{high}_{i,ps}$)		0.0437		0.0482
		(0.0318)		(0.0306)
R$_{cit}$*G(P$^{strong}_{c,\ ps}$, I$^{medium}_{i,ps}$)		0.0607**		0.0675**
		(0.0298)		(0.0326)
R$_{cit}$*G(P$^{strong}_{c,\ ps}$, I$^{low}_{i,ps}$)		0.0199		0.0161
		(0.0251)		(0.0279)
R$_{cit}$	-0.0110	-0.0116	-0.0185	-0.0185
	(0.0261)	(0.0242)	(0.4183)	(0.0228)
Knowledge stock control as in Table 5	Yes	Yes	Yes	Yes
Controls for G(*)$_{ci}$-groups	No	Yes	No	Yes
Country-year effects	Yes	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes	Yes
Observations	2,592	2,592	2,761	2,761

Note: In columns 1 and 2 we provide OLS estimates of R&D intensity models with financial interaction terms for the sub-sample where all observations with missing values of the private credit measure are eliminated from the main sample, as used in Table 4. Country-industry groups are indicated by G(·). The variable *Financial Development(FD)*$^{high}_{c,\ ps}$ is coded one for countries where the private credit measure takes values at or above the 75 percentile of the sample distribution, otherwise zero. We divide the country-group with high financial development into industry-specific sub-groups according to our measure of reliance on external finance, *External finance (E)*$^{high}_{i,\ ps}$: the group with low (high) reliance covers the industries below the 25th percentile (at or above the 75th percentile) of the sample distribution of the reliance measure, and the group with medium reliance covers the remaining industries. Reliance on external finance in industry i is defined as reliance in the corresponding US industry during the 1980s, provided by Rajan and Zingales (1998). In columns 3 and 4 we provide OLS estimates of R&D intensity models with knowledge stock interaction terms for the main sample. The country-industry group *G(Knowledge stock*$^{high}_{ci,1986}$*)* consists of the country-industries where the knowledge stock control, defined as in Table 4, takes values at or above the median of the sample distribution, otherwise zero.
All other variables are defined as in Tables 4 and 5. Standard errors in parentheses are robust and clustered to allow for unrestricted correlation between annual observations within country-industries. Statistical significance at the 1%, 5% and 10% level is indicated by ***, ** and *.

Appendix A: Additional Tables

Table A-1: Definitions of variables and descriptive statistics

Variable	Definition	Mean/ share	Standard deviation
R&D intensity$_{cit}$	nominal R&D expenditures divided by nominal value added in industry i in country c and year y	0.0464	0.0734
Real R&D expenditures$_{cit}$	R & D expenditures at constant prices in 2000 converted to US dollars using purchasing power parity rates (in billion)	0.4443	1.1583
Patent count$_{cit}$	fractional count of patents taken out in 1000 in US Patent Office	0.1036	0.3012
Product market reforms$_{cit}$	share of 3-digit classes in industry i that are ex ante expected to be affected by the SMP reforms from 1992 onwards; 0: otherwise	0.3027	0.3076
Protection$_{ct}^{Ginarte/Park}$	patent protection index (Park, 2008, Ginarte & Park, 1997) taking values 0 to 5 & higher values in country- -years ct with patent laws providing stronger IPR	3.9029	0.7067
Protection$_{c,\ pre-sample\ (ps)}^{strong}$	1: country c with strong patent rights since the pre-sample period, 1980 to 1986 0: otherwise	0.5389	
Protection$_{c,\ ps}^{weak}$	1: country c with weaker patent protection in the pre-sample period and later on, 0: otherwise	0.4611	
Patent intensity $_{US,\ i,\ 1983}$	number of patents divided by nominal value added in million US dollar in US-industry i in year 1983	0.0463	0.0367
Knowledge stock$_{ci,\ 1986}$	knowledge stock in country-industry ci in 1986 (perpetual inventory method, depreciation rate: 20 %)	0.3684	1.0725
Ratio of private credit$_{c,\ ps}$	average claims of deposit money banks & other financial institutions on the private sector relative to GDP in 1980-1986 (Beck et al., 2010b)	0.6279	0.1938
Financial development$_{c,\ ps}$	1: country c with private credit ratio in pre-sample period at or above 75 percentile of the sample distribution, 0: otherwise	0.3111	
Ratio of external finance $_{US,\ i,\ ps}$	share of capital expenditures that firms in US-industry i during the 1980s can't finance through internal cash flow (Rajan and Zingales, 1998)	0.3049	0.2490
Ratio of stock market capitalization$_{c,\ 89/90}$	average value of listed shares relative to GDP in 1989-1990 (Beck et al., 2010b)	0.3182	0.2612

Notes: This table provides non-weighted descriptive statistics for our main sample, an unbalanced panel of 2,761 observations on 13 manufacturing industries in 17 European countries between 1987 and 2003.

Table A-2: Identification using alternative sources of data variation

	Dependent variable: R&D intensity$_{cit}$		
	Sample including...		
	...SMP-countries only	...the United States	...service industries
Panel A	OLS	OLS	OLS
	(1)	(2)	(3)
Explanatory Variables:			
Product market reforms $(R)_{cit}$	0.0775***	0.0859***	0.0864***
$*G(\text{Protection } (P)^{strong}_{c,\ pre-sample\ (ps)})$	(0.0244)	(0.0233)	(0.0149)
R_{cit}	-0.0109	-0.0180	0.0029
	(0.0312)	(0.0228)	(0.0132)
Knowledge stock control as in Table 4	Yes	Yes	Yes
Country-year effects	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes
Observations	2,025	2,982	4,030
Panel B	OLS	OLS	OLS
	(4)	(5)	(6)
Explanatory Variables:			
$R_{cit}*G(P^{strong}_{c,\ ps}, \text{ Patent relevance } (I)^{high}_{i,\ ps})$	0.0755**	0.0653**	0.0381
	(0.0305)	(0.0263)	(0.0259)
$R_{cit}*G(P^{strong}_{c,\ ps}, I^{medium}_{i,\ ps})$	0.0811***	0.0718***	0.0668***
	(0.0263)	(0.0242)	(0.0207)
$R_{cit}*G(P^{strong}_{c,\ ps}, I^{low}_{i,\ ps})$	0.0190	0.0378	0.0038
	(0.0261)	(0.0262)	(0.0149)
R_{cit}	-0.0182	-0.0181	0.0054
	(0.0323)	(0.0212)	(0.0125)
Controls for the $G(*)_{ci}$-groups	Yes	Yes	Yes
Knowledge stock control as in Table 4	Yes	Yes	n.a.
Country-year effects	Yes	Yes	Yes
Industry-year effects	Yes	Yes	Yes
Observations	2,025	2,982	4,030

Notes: The R&D-intensity model estimates in column 1 is for the sub-sample, resulting after eliminating all non-SMP countries from the main sample, as used in Table 4. The estimates in column 2 are for the extended sample covering the main sample plus the data for the US. For the estimates in column 3 we add data for all 8 available service industries to the main sample; note that patent data is not available for service industries and, thus, we estimate models without the patent-based controls for the initial innovative potential of country-industries.
All variables are defined as in Tables 4 and 5. Standard errors in parentheses are robust and clustered to allow for unrestricted correlation between annual observations within country-industries. Statistical significance at the 1% and 5% level is indicated by *** and **.

Appendix B: Data sources and variables

B.1 Research and development expenditures

Our main measure of innovation is *R&D intensity*, that is nominal R&D expenditures as a percentage of nominal value added. For calculating that measure we use country-industry-year level data on research and development expenditures from the OECD ANBERD database (edition 2011, `www.oecd.org/sti/anberd`)[1] and data on value added from the EU KLEMS database (2008 version, `http://www.euklems.net/index.html`).[2] We also consider *real R&D at constant prices of the year 2000 converted to United States (US) dollars using purchasing power parity rates.*[3]

B.2 Patenting

The country-industry-year-specific *patent counts* which we use were constructed by the EU KLEMS consortium. They aggregated the NBER patent data (2002 version, `http://elsa.berkeley.edu/~bhhall/patents.html`) on patents granted by the US Patent and Trademark Office per year at the country-industry level, including data for patents applied for up to the year 1999 (O'Mahony, Castaldi, Los, Bartelsmann, Mainaiti and Peng, 2008; Hall et al., 2001). Patents are assigned to years according to the application date recorded in the patent document and to countries according to the country of the first inventor. For our main empirical analysis we use the fractional patent count where each patent is counted in all n OTAF classes it is assigned to with a weight of $1/n$. The patents are assigned to up to 7 OTAF classes and all classes (41 OTAF classes, plus one "other industries" class) are mapped into EU KLEMS industry classes (see O'Mahony et al., 2008, for further details).[4]

To construct the *knowledge stock built up during the pre-sample period* in each country-industry we use pre-sample patent information, the perpetual inventory method, and an annual knowledge depreciation rate of 20 percent. The knowledge stock is defined as the sum of the fractional patent counts, refer to the pre-sample period, are depreciated to the last year of the pre-sample period and divided by 1000.[5]

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[1] For Denmark and Sweden we add in the data from ANBERD 2009. These countries have been missing in ANBERD 2011 until we completed the empirical analysis that we provide here.

[2] The EU KLEMS Growth and Productivity Accounts provide country-industry level panel data based on data from national statistical offices and designed to ensure international comparability. The EU KLEMS project was a joint initiative of several academic institutions and national economic policy research institutes, supported from various statistical offices and the OECD, and funded by the European Commission (O'Mahony and Timmer, 2009).

[3] To calculate the required series of value added at year 2000 prices converted to US dollars, we draw nominal value added and the related price index, re-based from 1995 to 2000, from EU KLEMS 2008 and convert to US dollars using the economy-wide purchasing power parity rates as provided along with ANBERD 2011.

[4] Our main empirical findings are robust to using total patent counts where each patent is counted with full weight in each class it is assigned to.

[5] Our main empirical findings are robust to using alternative depreciation rates; we also tested 10 percent and 30 percent.

B.3 Patent Rights

To measure the strength of patent rights, that is intellectual property rights (IPR) as laid down in patent laws,[6]we prefer to distinguish between countries with strong and weak patent rights using information on patent law reforms and related regulation.[7] The following countries had strong patent protection regimes before 1987 and maintained strong regimes throughout the whole sample period: Belgium, Denmark, France, Germany, Italy, Netherlands, Sweden, and the United Kingdom (plus the United States). The countries with weaker patent protection regimes completed the major patent law reform preparing the ground for a strong patent protection regime in 1992, or even later: Czech Republic, Finland, Greece, Hungary, Ireland, Poland, Portugal, Spain, and the Slovak Republic.

All European countries that we classified as having strong patent rights, except for Denmark, have been among the initital contracting states of the European Patent Organisation (EPOrg) since October 1977. The EPOrg is the intergovernmental organization that was created in 1977 by its contracting states to grant patents in Europe under the European Patent Convention of 1973; the European Patent Office (EPO) acts as the executive body for the Organization. All the countries classified as having weaker patent rights joined the EPOrg between October 1986 and March 2004 (EPOrg, 2012) and none of these countries completed the reforms preparing the ground for a strong patent protection regime before 1992 (Branstetter et al., 2006, Qian, 2007, WIPO, 2012). Our classification is fully consistent with the groupings in Branstetter et al., 2006 or Qian, 2007. It also fits with the patent right index constructed by Maskus and Penubarti (1995): The patent laws of all the countries that we classify as countries with strong patent rights were fully conforming with the minimum standards of the US Chamber of Commerce Intellectual Property Task Force in 1984 (Maskus and Penubarti, 1995); the patent laws of all other countries did not fulfill it in 1984 or were planned economies not covered by Maskus and Penubarti (1995).

For robustness checks, we also use the index of patent protection that was developed by Ginarte and Park (1997) and updated by Park (2008). Park (2008) provides the index data for 110 countries, updating it quinquennially between 1960 and 2005. The index takes values between zero and five and higher values indicate patent laws with stronger IPR. The index coding scheme aggregates information on 1) membership in international patent agreements (Paris Convention 1883, International Convention for the Protection of New Varieties of Plants 1961, Patent Cooperation Treaty 1970, Budapest Treaty 1977, Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) 1994), 2) provisions for loss of protection (working requirements, compulsory licensing, revocation of patents), 3) enforcement mechanisms (preliminary injunctions, contributory infringement pleadings, burden of proof reversal), 4) duration of protection and 5) extent of coverage (pharmaceuticals, chemicals, food, surgical products, microorganisms, utility models, software, plant and animal varieties). Relevant in the context of our study is the updated

[6]The strength of patent rights and the strength of other forms of IPR, in particular copyrights and trademarks, tend to be strongly correlated.

[7]See, in particular, Branstetter, Fisman and Foley, 2006, Lerner, 2000, Maskus, 2000, Maskus and Penubarti, 1995, Qian, 2007, and World Intellectual Property Organization, 2012.

coding scheme described in Appendix A of Park (2008); Ginarte and Park (1997) give details on the original coding scheme.

We classify industries according to the extent to which innovators rely on patenting and, thus, should respond to the strength of patent rights, forming industry groups with different levels of *patent relevance*. To do so, we first calculate the nominal patent intensity for US industries in all pre-sample years 1980 to 1986, dividing the fractional patent counts by nominal value added in million US dollars.[8] Then, we form industry groups, exploiting the fact that the ranking of US industries based on the calculated patent intensity is very persistent across the pre-sample years: the group with high patent relevance covers the three sampled industries that constitute in all years the industries with the three highest patent intensities; the group with low patent relevance covers the three industries that score lowest, and the remaining seven industries form the intermediate group. Alternatively, we form two groups. One group consists of the six industries that constitute in all years the industries with the six highest patent intensities and are, thus, above the median, and the other group complements.

B.4 Product market reform

The product market reform that we focus on constitutes a substantial part of the large-scale European Single Market Program. With the SMP, as designed by the European Commission and, thus, at a supra-national level, the EU aimed at bringing down barriers to the free movement of products and production factors within the EU in order to foster competition, innovation and economic growth. Recent empirical evidence supports the view that product market competition increased in response to the SMP product market reform.[9] The SMP was officially implemented in 1992 in all sampled countries that had joined the EU before 1992: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, United Kingdom.

For these SMP countries, the European Commission report by Buigues et al. (1990) provides a common list of 40 three-digit manufacturing industries that were ex ante expected to be affected differently by the SMP. Additions to and removals from the common list are also reported for each sampled country. These additions and removals reflect recommendations of experts, who were asked whether they expected the reform to change the product market conditions in an individual industry in a specific country differently than in the corresponding average industry in SMP countries. The reform measures that can be derived from the information in Buigues et al. (1990) vary across countries, industries and time; a fact which we exploit to identify the reform impact from confounding influences. As our main data set covers non-SMP countries as well, we can also use further data variation across countries.[10]

To construct our main measure of the product market reform we aggregate the information

[8] Using data on US industries is advantageous here as the US is the worldwide leading innovator in most industries and it is not included in our main sample.

[9] See, for example, Bottasso and Sembenelli (2001), Badinger (2007), or Griffith et al. (2010).

[10] In section 5.3, we show the estimation results for the sample of SMP countries only.

in Buigues et al. (1990) as follows:

$$R_{ict} = \begin{cases} \frac{1}{n_i} \sum_{j \in i} A_{jct} & \text{if } t \geq 1992 \\ 0 & \text{if } t < 1992 \text{ or } \sum_{j \in i} A_{jct} = 0 \end{cases}$$

The measure is set to zero in all years before the implementation of the SMP, from 1992 onwards it is equal to the share of three-digit classes j per two-digit industry i of SMP-country c that were ex ante expected to be affected by the SMP. The dummy variable A is coded one from 1992 onwards if a three-digit industry j in a country c was ex ante expected to be affected. The number of three-digit industries per two-digit industry is denoted by n_i.

Using our measure of the SMP product market reform, we can rank all industries in our data set. The resulting rank order corresponds to the rank order of Griffith et al. (2010), except for two deviations. Griffith et al. (2010) constructed a related, but different product market reform measure. In their data set the industry 'furniture, jewelery, games & toys, environmental technology, recycling' is missing; in ours the industry 'pulp, paper, printing & publishing' is missing. They used the information in Buigues et al. (1990) for the common list of affected industries, the removals from that list, the industry groups as used by the report, and the data on employment shares for weighting purposes. We, instead, also use the information on additions to the common list, but neither the industry grouping nor the employment shares for the following reasons: Greece and Portugal, for example, had many additions and these countries are included in our data set; Buigues et al. (1990) provide neither the industry grouping nor the employment shares for the industries that are added to the common list.

To address concerns regarding our main product market reform measure, we also consider alternative measures. First, we replace the reform intensity measure with an indicator which equals one for all values of the product market reform intensity above the median of the sample distribution in SMP-affected country-industries, and else zero. Then, the estimation results turn out to be consistent with those in columns 4 of Tables 4 and 5. Second, while we prefer to use the main SMP implementation year (1992) as switching point from zero to positive reform intensity values,[11] we also construct an indicator that takes values above zero already from 1988 onwards. This adds as SMP years the years where first information on expected SMP effects became available and where some initial implementation steps were undertaken.[12] When using that alternative measure, the estimation results are again in line with those in columns 4 of Tables 4 and 5.

[11]The empirical findings of Badinger (2007), among others, provide support for this decision and Griffith et al. (2010) also chose that approach.

[12]Bottasso and Sembenelli (2001) and Aghion et al. (2009) took that approach.

B.5 Financial variables

For the financial variables which we use in section 5.3 of the paper we use data from the November 2010 version of the Financial Development and Structure Database by Beck et al. (2000, 2010b) and from Rajan and Zingales (1998).[13]

First, we classify countries according to the level of their financial sector development using data on the channeling of savings to investors by financial intermediaries relative to the size of the economy. Our preferred measure from the Financial Development and Structure Database is the following private credit ratio: claims of deposit money banks and other financial institutions on the private sector, relative to gross domestic product (GDP). The ratio is available for all sampled countries, except the Czech Republic and the Slovak Republic, for at least four pre-sample years between 1980 and 1986. We average all pre-sample entries per country and classify the countries with averages at or above the 75 percentile of the sample distribution as having a highly developed financial sector. These countries are France, Germany, the Netherlands and Sweden.

Our alternative measure of high financial sector development is based on stock market capitalization, that is the value of listed shares, relative to GDP. As data on this stock market measure is hardly available before 1989, we average across the years 1989 and 1990.[14] The countries with averages at or above the 75 percentile of the sample distribution are classified as those with high financial sector development, namely Belgium, Netherlands, Sweden and the United Kingdom.

Second, we separate between industries that differ in their reliance on external finance. To that aim we use industry-level data on the share of capital expenditures that firms cannot finance internally: the ratio of firms' capital expenditures minus cash flow from operations, divided by capital expenditures. Rajan and Zingales (1998) provide that data for US industries during the 1980s. We link the industries in our sample to the corresponding US industries and then distinguish three industry groups. The group with low reliance on external finance covers the industries with ratios below the 25th percentile of the sample distribution, the group with high reliance on external finance covers the industries with ratios at or above the 75th percentile, and the remaining industries form the medium group.

Appendix C: Construction of main estimation sample

Our main estimation sample is an unbalanced panel of 13 industries in 17 countries between 1987 and 2003. We apply the following standard data cleaning routines. We drop country-industry-year observations with missing values of variables that are relevant to our regression analysis. In addition, we eliminate a few observations with negative R&D expenditures or unreasonably small, positive R&D expenditures (below 1500 Euro) and all

[13] See `http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:20696167~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html`.

[14] Even for these years, missing data prevents us from calculating the measure of stock market capitalization for the Czech Republic, Hungary, Ireland, Poland, and the Slovak Republic.

observations with absolute R&D expenditure growth of more than 200 percent. Finally, we eliminate all country-industries where we observe less than five consecutive years.[15]

Due to restrictions regarding patent data availability, our patent sample is limited to the observation period between 1987 and 1999. When setting up the patent sample, we eliminate all country-industries of the 13 industries in the 17 countries where we observe less than five consecutive years within this time period.[16]

[15]In case of country-industries with two separate series with at least five observations, we select the earlier one.

[16]Cases with two separate series of sufficient length do not arise.