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The influence of regulations on innovation: A quantitative assessment for OECD countries

Knut Blind [a,b,c]

[a] Berlin Institute of Technology, Chair of Innovation Economics, VWS 2, Müller-Breslau-Straße, 10623 Berlin, Germany
[b] Fraunhofer Institute for Open Communication Systems, Kaiserin-Augusta-Allee 31, 10589 Berlin, Germany
[c] Erasmus University, Rotterdam School of Management, Chair of Standardisation, Burgemeester Oudlaan 50, 3062 PA Rotterdam, The Netherlands

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ABSTRACT

Regulatory framework conditions have been identified as important factors influencing the innovation activities of companies, industries and whole economies. However, in the empirical literature, the impacts of regulation have been assessed as rather ambivalent for innovation. Different types of regulations generate various impacts and even a single type of regulation can influence innovation in various ways depending on how the regulation is implemented. The endogenous growth approach developed by Carlin and Soskice (2006) and empirically applied by Crafts (2006), which determines endogenously the rate of technological progress and therefore innovation, allows a conceptual analysis of the influence of different types of regulation on innovation. In general, the negative effect of compliance costs should be compared with the more dynamic effect of regulations generating additional incentives for innovative activities. Based on this approach, we derive hypotheses on the impact of different specific regulations on innovation.

We differentiate between economic, social and institutional regulations following the OECD taxonomy on regulations. Existing economic analyses are surveyed, which are characterised by rather heterogeneous approaches, data bases and results. The paper aims to apply a comprehensive and comparative approach to investigate quantitatively the innovation impacts in 21 OECD countries using panel data for the period between 1998 and 2004. In summary, the empirical results confirm the hypotheses derived from the conceptual theoretical framework determining technical progress and innovation endogenously and allowing a distinction between short-term and long-term effects. Consequently, the theoretical approach is an appropriate starting point for the empirical analysis of the influence of different regulations on innovation.

1. Introduction

Regulation, innovation and competitiveness in global markets have been discussed for several decades. However, little progress has been made to understand the effect of regulation on the ability of industries to innovate. At the beginning of the studies, the debate took place at the level of anecdotal evidence and with poor systematic empirical foundations, which has changed recently towards more analytical and broad empirical analyses. However, before giving an overview of quantitative empirical studies, it has to be mentioned that the case study approach is certainly very appropriate to analyse the influence of the regulatory framework on innovation in very specific markets. Examples of recent studies in tissue engineering (Faulkner, 2009), agrobiotechnology (Chataway et al., 2006) and pharmaceuticals (Abraham and Davis, 2007) demonstrate the scientific and pragmatic value of such detailed analyses often based on social or political theory.

Innovation policymakers have started to shift their focus towards the regulatory framework as a possible policy instrument (Blind et al., 2004). However, they have little leeway to increase public spending in R&D in order to promote innovation due to public budgets restrictions. Therefore, policies to improve the framework conditions relevant for innovation are becoming more important. Consequently, regulatory impact assessments as an important instrument for regulatory policies, should not only consider the burden for companies to fulfill specific regulations, but should also take into account possible impacts on innovation.

Policymakers are trying to limit the negative impacts of regulation on the innovative activities of industry, and have started to look more systematically for options to use specifications of the regulatory framework to promote these activities. Static efficiency concepts are not sufficient to achieve this aim; instead, dynamic considerations are required, as they allow at least for temporary static inefficiencies. However, the extension of the traditional

E-mail address: knut.blind@tu-berlin.de
URL: http://www.inno.tu-berlin.de.

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objectives of regulatory policies to innovation-related goals needs to be systematically checked for possible conflicts or synergies. For example, the introduction of new pharmaceuticals may conflict with safety considerations, due to the lack of long-term experience whereas environmental protection can often be achieved by innovative environmental technologies, which is more likely to be a win-win constellation.

The objective of this contribution is to assess the impacts of regulation on innovation, taking into account the variety of regulations, their ambivalent impacts and their dynamic relationship. In order to conduct such an analysis of the impact of six different types of regulations on innovation, which covers 21 OECD countries and a time period of six years, we have to make rather rigorous assumptions. First, we assume impact mechanisms of regulation on the aggregate innovation activities and success not only among the considered OECD countries, but secondly among the different types of regulations also within a country. Based on the applied conceptual model presented in Chapter 2, we distinguish only between the impacts of compliance cost on the availability of resources for innovation on the one hand and the incentives set for performing innovation activities on the other hand. Other impacts like feedback loops between the regulator and the regulated company, learning from each other for example, are not taken into account. Thirdly, the influence of regulation on innovation over time is assumed to be constant. These are indeed rigorous assumptions. However, a comparative dynamic cross-country analysis of the influence of different types of regulation on innovation requires such a rigorous approach in order to derive such general insights. An analysis on such an aggregate level has to be complementary both to sector-specific quantitative studies and to very detailed case-based studies, which are able to reflect more the specific interactions between setting regulations and the reaction regarding innovation on the company level.

2. The influence of regulation on innovation: a theoretical approach

We discuss the impact of regulation based on the considerations of Carlin and Soskice (2006), who determine an equilibrium rate of technological progress and consequently innovation endogenously. Starting from the Solow growth model, we can derive a negative relationship between the rate of labour productivity enhancing technological progress or innovation i – analogously to an increasing population or labour force – the equilibrium capital intensity k. This relation is also named the Solow relation. In contrast, the Schumpeter relation assumes that with increasing capital intensity k, more resources are available for investments in research and development, which allows innovation and the rate of technical progress i to increase (Fig. 1).

If we introduce regulation into this equilibrium scheme, we have to consider two effects. First, the compliance of regulations reduces – like a tax – the available resources for investment in research and development. Consequently, we observe a lower capital intensity k and a reduced level of technical progress and innovation i (Crafts, 2006). Second, regulation changes the incentives for investments in R&D. Regulatory schemes, such as patent protection, may create additional incentives to invest in R&D (Carlin and Soskice, 2006) whereas others such as price restrictions and product market rules, may reduce incentives (Crafts, 2006). The impact on innovation depends on the extent of the compliance cost and the incentive effect. We see a positive impact on the rate of technical progress (i_1), if compliance costs are low or even zero and the incentives are positive and a negative (i_2) impact especially with high compliance cost and low or even negative innovation incentives (Fig. 2).

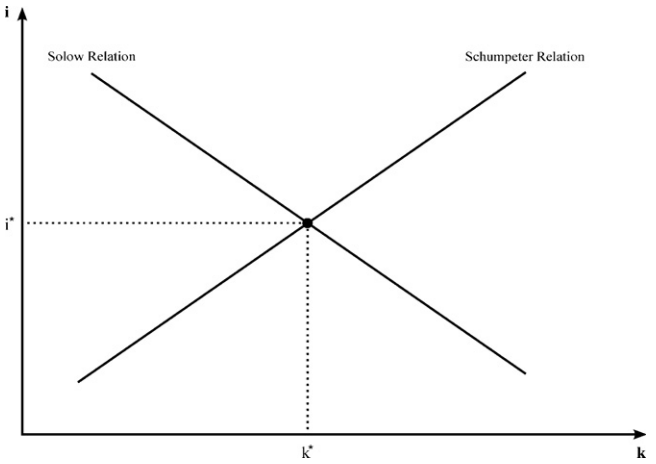

Fig. 1. The endogenous determination of innovation. Source: Carlin and Soskice (2006).

The theoretical model shows that it is necessary to differentiate specific types of regulation for an empirical analysis of the impact of regulation on innovation. The term regulation generally refers to the implementation of rules by public authorities and governmental bodies to influence market activity and the behaviour of private actors in the economy. Such intervention in the market is justified to maximize collective welfare, including reaching some distributive goals. Economic literature and particularly the OECD (1997) distinguish economic, social and institutional regulations. Economic regulation is trying to avoid market failures generated by the behaviour of single players within the markets. Competition policy in general aims to provide framework conditions which lead to a minimum level of competition among the actors active in the market. More specifically, price regulation is used to protect either the demand side or a too fierce competition on the supply side. If entry barriers for newcomers are too high, market entry regulations aim to lower these hurdles. Finally, in some markets, single suppliers or public provision of goods and services are efficient from a static allocation efficiency perspective. However, regulation of natural monopolies and public utilities might become necessary from a dynamic efficiency perspective. Social regulation is targeting to reduce or prevent negative externalities. Such externalities are most prominent in the environmental context. Consequently, environmental regulation is most relevant for policy makers especially in last years and increasingly analysed by researchers of

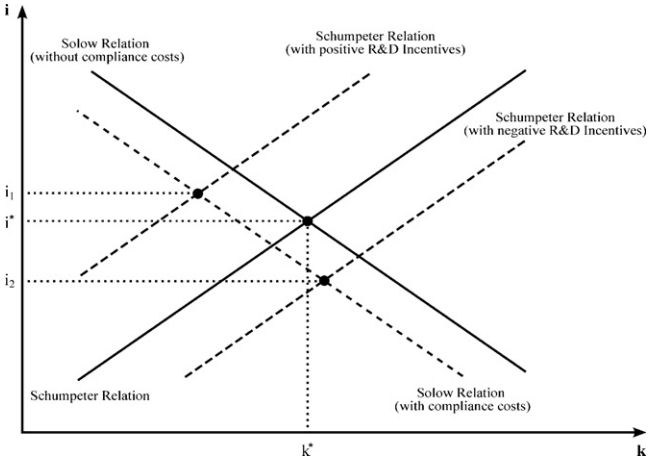

Fig. 2. The influence of regulation on the endogenous determination of innovation. Source: Crafts (2006).

various disciplines. However, products and production processes can also hurt the consumers or the labour force. Therefore, we consider also labour and consumer safety regulations. Finally, the institutional regulations are rather generic framework conditions either based on liability law, which has in the case of product liability overlaps with the already mentioned products safety regulations, or the definition of intellectual property rights, which are decisive for innovation. Finally, since the empirical part of the paper is based on OECD countries, we follow this OECD taxonomy.

The next sections will explain the context of their impact on innovation.

2.1. The impact of economic regulation on innovation

Among economic regulations, we differentiate and focus on competition policies, price regulation, market entry regulations, and the regulation of natural monopolies and public utilities.

In general, competition enhancing and securing policies increase the incentives for companies to invest in innovation activities in order to escape – at least partly – fierce competition. However, if competition becomes so intense that imitation activities become more attractive than innovation activities, the positive impact may change into a negative one according to empirically proved inverse U-shape between competition and innovation intensity (Aghion et al., 2005). In addition, if competition regulation restricts the cooperation between companies in research and development, such innovation activities may not be initiated and possible efficiency gains cannot be exploited.

The impacts of price regulations on innovation depend crucially on their specific implementation. If price regulation results in innovation companies securing certain minimum revenues or reducing their risk on the demand side, then the incentives to innovate increase, whereas the compliance cost are negligible.

Market entry regulations increase the hurdles for companies to enter a specific market. This may be positive for the incumbents, because it reduces the competitive pressure and allows them to invest more resources in risky innovation activities. However, market entry barriers make it very difficult for innovative companies to enter markets, which is negative for the overall innovative performance in these markets.

The regulation of natural monopolies and other public utilities has been a crucial issue over the past decades resulting in the liberalisation and privatisation of several originally publicly dominated markets. Under the regulatory framework in the 1960s and 1970s, monopolies and public utilities had no strong or biased incentives to innovate. Therefore, in the 1980s, the United States started to implement regulations to motivate them to make productivity gains and achieve innovations. However, these new regulatory principles reduced the rents of the regulated firms which were often used for large R&D projects and other innovation activities. Therefore, an incentive-financing dilemma emerged for some public utilities.

Especially network-based services, such as telecommunications, water and energy supply, were regulated under the old principles of rate of return regulation or pricing at marginal costs. The rate of return regulation states that a monopoly should not achieve a profit higher than the average firm in the industry. Under marginal cost pricing, the monopoly was forced to price its products according to two-part tariffs (Ramsey-Pricing).

These regulatory schemes were responsible for the low or biased technical progress towards capital intensive production (Averch and Johnson, 1962) and resulted in little innovation in some regulated industries, such as telecommunication and energy. Based on the progress of the economics of information (Stiglitz, 1975), appropriate incentive schemes were developed to overcome the information asymmetries between regulated companies and regulatory bodies. This led to the implementation of new regulatory measures based on the idea that there is a 'revelation-incentives' dilemma that can be solved by fine tuning via 'price cap' regulation. Price cap regulations are based on contracts between the regulator and the regulated firm, which require minimum quality and fixed maximum prices. If the regulated firm can realize some additional profits by productivity gains, incentives for innovation are created, whereas if the regulatory body wants to capture all revenues from productivity gains, the regulated firms have no incentive to innovate. The same is true if the regulatory framework implements competition, which allows multiple suppliers with inefficient cost structures. Consequently, they try to increase their market shares by price competition, which reduces their profits and hampers investment in R&D and innovation (Table 1).

2.2. The impact of social regulation on innovation

The impact of social regulations on innovations has been less frequently analysed. Most of the existing literature on social regulations and their impact on innovation is focused on the analysis of the impact of environmental regulation caused by the increasing importance of environmental issues (Kemp, 1998). In addition, new environmental regulations have resulted in the scrapping of existing machinery and equipment and enabled new entrants to introduce new production techniques into the industry. Environmental regulations have caused the emergence of new industries, such as the 'environmental industry', and of new products with fewer or almost no negative impacts on the environment. Consequently, environmental regulations drive the industry explicitly towards technologies which protect the environment or produce less environmental damage. For example, Kemp (1998) proposes to use regulation as a modulator of technical change, i.e. social regulation may change the direction of technical change to innovations with less negative impact on the environment. The innovation triggering effect of environmental regulations was perceived by Michael Porter in his famous Porter hypothesis stating that ambitious environmental regulations may be challenging for the national industry at the very beginning, but help to improve international competitiveness and to increase exports of the developed environmental technologies (Porter and van der Linde, 1995).

The counter-hypothesis postulates that environmental regulations restrict firms in their innovative activities and cause additional costs, which have a negative impact on their competitiveness and consequently also on their capability to innovate. It is consensus that the regulation of end-of-pipe technologies has these negative effects, whereas the regulation of integrated environmental protection may be ambivalent for innovation.

In sectors with strong ethical dimensions and a high importance of externalities, such as the health sector, the activities and strategies of the actors involved are so bound by regulations, that the link between regulation and innovation is obvious and close. On the one hand, safety regulations may prohibit innovations, if public authorities forbid presumably risky products and therefore likely radical innovations. On the other hand, these regulations increase the acceptance of new products and services among consumers, since they can rely on some minimum product safety. However, especially the health sector is affected by various other means of intervention (Day and Frisvold, 1993). Consequently, the perspective has to be broadened from the single regulation to the institutions that surround the regulatory framework.

Most policies on public goods fit into the logic of direct intervention rather than the logic of regulation. Nevertheless, the provision of public goods generally fosters innovation if they represent physical (road system) or intangible (education) infrastructures. However, individual economic agents are deprived in their

Table 1
Incentive effects and compliance costs of economic regulations.

Economic regulation			
Type of regulation	Compliance cost or negative incentive effects	Positive incentive effect	Net effect
Competition enhancing and securing regulation	Prohibits R&D cooperation	Increases and secures incentives to invest in innovation	positive
Price regulation	Price caps reduce innovation incentives	Minimum prices secure minimum turnovers and decrease risks; completely free prices allow monopoly pricing	positive in case of flexible prices
Market entry regulation	Prohibits market entry of probably innovative newcomers	Reduces competition for incumbents, e.g. for infant industries	negative
Regulation of natural monopolies and public enterprises	High price pressure and low gains allow no investments into R&D in case of marginal cost pricing	Incentives to achieve progress in productivity in case of rate of return regulation	positive in case of deregulation

innovative activities, because they have to transfer funds via taxes to public institutions (Table 2).

2.3. The impact of institutional regulation on innovation

Besides single economic and social regulations, the institutional framework implemented by administrative regulations is essential for the analysis of regulation and innovation. Two approaches have been developed to link the legal framework to innovation.

The economic analysis of law has also focused on how the legal environment influences economic efficiency, including innovation. Especially the impact of liability rules on innovation, particularly in the domain of product safety has been analysed. If liability rules are too strict, innovators do not introduce new products and services in the market – especially radical innovations, because the risks are high, the expected revenues decrease, and the users of the products reduce their self-protection efforts, leading to more accidents. Viscusi and Moore (1993) confirm empirically that very high levels of liability have negative effects on product innovation. However, without product liability, the acceptance of new products among consumers is reduced which may prohibit their success in the market (Table 3).

3. Overview of empirical studies

The best analysed link between administrative or institutional regulation and innovation is the impact of Intellectual Property Rights (IPRs), especially patents and copyrights, on innovation. Besen and Raskind (1991) point out that the fundamental dilemma lies between invention and diffusion. On the one hand, a strong patent protection encourages innovation. On the other hand, a weak one favours a rapid and wide diffusion of inventions, which leads to innovations and growth for the whole economy. Appropriate licensing schemes may be a good way to reach the two goals simultaneously. Since innovation processes differ by industries, optimal IPR rules should also vary from industry to industry from a purely economic point of view, but this is not practicable for the legal system. In general, institutional regulations can provide positive incentives for innovative activities, but force suppliers of new products and services to introduce less risky products and services into the markets.

Although there is no real tradition of empirical studies on the influence of regulation on innovation, there are several studies which assess the influence of the three different types of regulation on innovation: economic, social and institutional. The most important of these studies will be presented in the following sections.

The topic of regulation, innovation and their impact on competitiveness in global markets has been discussed for several decades. However, until recently, little has been done to understand the effect of regulation on the ability of industries to innovate and to be competitive. The debate has taken place at the level of anecdotal evidence and with poor systematic empirical foundations at the beginning of the studies, which has changed recently towards more analytical and broad empirical analyses. Starting with an analysis of some empirical studies on the impact of economic regulations on innovation, Bassanini and Ernst (2002) find a negative correlation between the intensity of product market regulations and the intensity of research and development expenditure in OECD countries. Swann (2005) examines a significant number of British companies and shows that the content of regulations is an important source for innovation but also a severe obstacle for innovation activities. In a study focusing on the telecommunication sector in the United States, Prieger (2002) confirms a negative influence of stricter regulation on service innovations proposed by telecommunications providers. Besides these studies, there is a tradition of research on the influence of competition and antitrust

Table 2
Incentive effects and compliance costs of social regulations.

Social regulation			
Type of regulation	Compliance cost or negative incentive effects	Positive incentive effect	Net effect
Environmental protection	Restricts innovation and creates compliance costs	Creates incentives for development of new eco-friendly processes and products (incl. environmental technologies) by creating temporary market entry barriers	ambivalent in the short run, but positive in the long run
Labour force protection	Restricts innovation and creates compliance costs	Creates incentives for development of processes with higher labour safety by creating temporary market entry barriers and monopoly gains	ambivalent, slightly negative
Product and consumer safety	Restricts innovation and creates compliance costs	Increases the acceptance of new products among consumers and promotes their diffusion creating innovation incentives	ambivalent, slightly positive

Table 3
Incentive effects and compliance costs of institutional regulations.

Institutional regulation			
Type of regulation	Compliance cost or negative incentive effects	Positive incentive effect	Net effect
Product liability	Too high liability risks reduce the incentives to develop and market innovative products	Increases the acceptance of new products among consumers and promotes their diffusion creating innovation incentives	ambivalent, but slightly positive
Intellectual property rights	Restrict development (e.g. via patent thickets) and the diffusion of new technologies and products and the option to develop	Create additional incentives to invest in R&D by appropriating temporary monopoly rights (plus increasing R&D efficiency by disclosure of technological knowhow)	positive

regulation on innovation. Koch et al. (2004) detect a positive impact of antitrust regulation on the R&D intensity in former G7 countries. This is in line with Geroski, who finds a positive correlation between competition intensity and innovation activities in British sectors (Geroski, 1991). Aghion et al. (2005) continue this research tradition and find an inverse U-shaped relation between competition intensity and patents as innovation indicators in the United Kingdom. Besides these broad studies about the impacts of competition intensity indirectly influenced by regulation, there are only very few sector specific studies focusing on the direct influence of competition shaping regulations on innovation. Such an example is the Orphan drug regulation focusing on rare diseases, which restricts the market to a single pharmaceutical company investing R&D to find new chemical entities as the basis for new drugs. This kind of infant industry regulation has been investigated by Reaves (2003), who finds a positive impact on pharmaceutical innovations.

A further field of research under the category of economic regulation is connected with the liberalisation of former public utilities or even monopolies. At first, the objective of these analyses was to develop instruments to achieve cost covering business models. Later, Averch and Johnson (1962) examined incentives schemes to increase the productivity of public utilities. In the 1990s the innovations of public utilities were triggered by the deregulation and liberalisation of former publicly owned or monopolised sectors. Various country studies (United States and Canada (OECD, 1999a, 1999b)) and sector studies (OECD, 1997) show that innovation significantly increased after the implementation of competition in markets such as transport and mains services.

Next we discuss studies focusing on social regulations, or more precisely, environmental regulations and their impact on innovation. Following the seminal contribution of Porter and van der Linde (1995), several further contributions (e.g. Jaffe et al., 1995; Jaffe and Palmer, 1997; Shadbegian and Gray, 2003) produce ambivalent results regarding the influence of regulation on the development of new environmental technologies. However, besides Porter and van der Linde (1995), Lanjouw and Mody (1996), Hart and Ahuja (1996) and the more recent studies by Brunnermeier and Cohen (2003), Popp (2006, 2002), Popp et al. (2007), Lanoie et al. (2008) and further studies listed in the survey by Gonzalez (2009) generally find, at least in the long run, positive impacts of environmental regulations on innovation.

In contrast to the large and growing literature, we see only a few empirical studies on the role of liability schemes on innovation following the seminal contribution by Viscusi and Moore (1993). They find a positive influence of liability law if the expected liability costs are moderate, but a negative impact, if the expected costs rise drastically. Other studies either show no impact on innovation (Papadakis et al., 1996) or even a tendency to promote existing technologies (Parchomovsky and Stein, 2008).

Finally, the regimes of intellectual property rights have been investigated in order to find empirical evidence for innovation promoting incentives and disclosure effects. In contrast to the expected and intended impacts, only very few studies, such as Koch et al. (2004), find a positive influence of IPR regulations on the R&D intensity in former G7 countries. In general, studies focusing on the innovation spurring impacts of patents either find no significant positive influence, see Bessen and Meurer (2008), or even negative implications, see Bessen and Hunt (2007) in the case of software patents on R&D activities in the United States. Also Lerner (2009) who examines impacts of strengthening patent protection over the last 150 years, concludes that patents may actually discourage investment in innovation.

The numerous empirical studies on the impact of different types of regulation on innovation present a rather heterogeneous picture both regarding the area of regulation, the time horizon of the impacts and the time period addressed. Although, different impact directions and strengths among the three types of regulations are expected, the actual empirical results show reverse results, such as strong positive impacts of environmental regulations also in the short run and even a negative influence of patent regimes. The studies also show differences between short and long term impacts. The short term impacts of regulations are often negative for innovation in contrast to the long term implications. Finally, it should be noted that the impacts are not time invariant, i.e. previous studies find slightly more negative impacts, whereas more recent investigations tend to reveal more positive implications especially of environmental regulations. Obviously, the increased environmental awareness during the last decades has led to positive impacts on innovation in environmental technologies. Finally, it has to be noted that especially the quantitative studies are not able to distinguish between the influence of changes in the legislation and their enforcement or the compliance of companies on innovation activities. For example, many European regulations are not enforced in the same way in the member states of the European Union, which consequently leads to different outcomes.

3.1. The data

The empirical analysis of the impact of regulation on innovation faces some serious data problems. First, the issue of adequate indicators for innovation is far from being solved or even leading, despite the a lot of progress in the last decades (Freeman and Soete, 2009), especially since current discussions also include non-technological aspects under a more comprehensive understanding of innovation. However, although we can rely on comparable data and even composite indicators (Grupp and Schubert, 2010) collected via the Community Innovation Survey for EU member states, which also reflects different types of innovation, such innovation indicators are not available for all OECD member states. Since our analysis covers 21 OECD countries and the conceptual model focuses on technological progress, we use patent applications listed with the US, the Japanese and the European patent offices as indicators for innovation success (as suggested by Archibugi and Coco (2005)). These triad patents are not biased according to regional influences. In order to correct for country size, we use the number of applications per employee (PATINT) (Frietsch and Schmoch, 2009).

Whereas patent applications represent objective innovation indicators which have been available for more than two decades, we face more serious problems regarding the regulation indicators. First, there are no time series available for objective fact-based regulation indicators. The OECD collected information on product market regulations (Conway et al., 2005). However, these indicators only cover some aspects of the economic regulations, but none of the other two categories. In order to take into account that changes in the regulatory framework will lead to delayed reactions of companies' innovation activities, we must use time series data. Since no time series of objective regulation indicators are available, we rely on the survey data provided by the International Institute for Management Development (2006) and World Competitiveness Yearbooks (World Economic Forum, 2006). These data are based on the opinions of industry representatives and are therefore likely to be biased. However, Pryor (2002) uses this data successfully to explain the general economic performance of OECD countries. Finally, a methodological study by Nicoletti and Pryor (2007) comparing three different studies and the work by Koch et al. (2004) using both objective information on governmental regulations and expert views, reveals a high correlation of the study results. This confirms that both objective and expert views capture the same underlying reality regarding the impact of governmental regulations. Therefore, we assume that these general methodological findings also cover regulations influencing innovation.

We use the assessment of the following six statements giving an indication of the influence of modifications of governmental regulations on innovation. The assessments indicate the level of agreement and range between 0 and 10.

We first focus on economic regulations. The general regulation of competition is covered by the following statement:

1. "Competition legislation is efficient in preventing unfair competition." (COMP)

The influence of price controls on price setting is represented by the following statement:

2. "Price controls do not affect pricing of products in most industries." (PRICE)

The general freedom of product market regulation is reflected by the statement:

3. "Product and service legislation does not deter business activity." (PRODUCT)

The social regulation is covered only by one statement focusing on environmental regulation, which also does not differentiate between end-of-pipe regulations, labelling schemes or integrated approaches:

4. "Environmental laws and compliance do not hinder the competitiveness of businesses." (ENVIR)

Finally, the general institutional framework conditions are characterised by the following two statements. The first statement focuses on the enforcement of intellectual property rights:

5. "Intellectual property rights are adequately enforced." (IPR)

The second statement addresses the general competition and therefore also innovation enhancing regulatory framework conditions:

6. "The legal and regulatory framework encourages the competitiveness of enterprises." (LEGAL)

Coming back to the theoretical considerations and the derivation of hypotheses in Chapter 2, we can expect that positive changes in the assessment of these six statements reflect a more innovation friendly regulatory framework, which should also lead to improved innovation performance. The assessments are rather general and we have to assume that they encompass both the legislations or regulations themselves and their enforcement. However, the six areas cover rather different aspects and have, as argued in Chapter 2, rather different impacts on innovation activities.

In order to control for the traditional factors influencing the performance of countries' innovation systems, we include the following variables into the multivariate regression approach. Since we use patents as innovation output indicators, we have to control for the input into the innovation process. Therefore, we use changes in the intensity of Business Enterprise Expenditure on research and development (RD) related to value added (OECD, 2006). Innovation activities do not depend only on the invested input, but are also driven by competition. In general, the competitive pressure of an economy can be measured by the import intensity (IMP) giving an indication on the influence of competition from abroad (World Trade Organization Statistics reported in International Institute for Management Development (2006)). The relevance of demand for innovation is increasingly accepted. Companies are forced to find innovative solutions if the demand is strong. We use export intensity (World Trade Organization Statistics reported in International Institute for Management Development (2006)) as an indicator for being successful in fulfilling the requests from demanding foreign customers. Countries can only increase export (EXP) if they respond to the preferences of their customers abroad. These customers, who are, due to the export into different countries, more heterogeneous, are likely to be more demanding than domestic customers. The broader the variety of the requirements from the demand side including higher needs, the more a company and therefore also an economy has to be successful in innovation.[1] Moreover, the requirements of domestic customers are increasing with the level of education, which is measured by changes of the Human Development Indicators (HDI) (Human Development Report reported in International Institute for Management Development (2006)). An increasing HDI enables an economy to improve its performance in innovation, because the qualification of human capital is essential for advancing innovative performance. Finally, the innovation system approach highlights the crucial role of cooperation (TEC) of all parties involved, which also generates additional spillovers. We take this aspect into account by including the changes in the technical cooperation of companies (International Institute for Management Development, 2006).

Since many of the regulatory variables have only been collected since 1998, our time series start in this year. Furthermore, some observations end in 2004. Since we use the differences, we have six observations, which are similar to the time series approach applied by Koch et al. (2004). However, changes in the regulatory framework should lead to changes in the innovative performance of an economy, especially since many new regulatory initiatives are often discussed more than one year before they are finally released.

Table 4 summarizes the variables used for the regression analysis.[2] The innovation indicator patent intensity (PATINT) is rather heterogeneous in the OECD countries, but increased significantly between 1998 and 2004. The same characteristics can be observed for the business expenditures on research and

[1] The export share reflects also the general openness of an economy, which is also an important factor for its innovation capacity in the sense of absorbing external know how to improve the own innovativeness.

[2] The following OECD countries are included in the analysis Austria, Belgium, Canada, Switzerland, The Czech Republic, Denmark, Finland, France, Germany, Spain, Hungary, Ireland, Italy, Korea, Japan, the Netherlands, Poland, Portugal, Sweden, The United Kingdom and The United States.

Table 4
Descriptive statistics.

	Mean	Std. deviation	1998	2004	Max.	Min.
PATINT	195.50	164.1615	174.90	212.87	638.08	2.16
RD	1.31	0.7468	1.22	1.34	3.32	0.11
IMPORT	39.29	19.6541	35.40	42.90	92.84	36.28
EXPORT	33.54	18.6743	28.85	35.25	85.68	31.85
HDI	0.92	0.0334	0.90	0.93	0.96	0.81
TEC	5.58	1.2069	4.83	6.47	8.34	2.97
COMP	6.13	1.0804	5.71	6.01	8.59	3.15
PRICE	7.41	1.0097	7.41	7.09	9.04	3.81
PRODUCT	6.56	0.8902	6.67	6.07	8.31	3.88
ENVIR	6.27	0.7734	6.27	6.12	8.03	4.13
IPR	7.24	1.3446	6.32	7.07	9.15	2.92
LEGAL	5.81	1.5704	5.39	5.12	8.53	2.21

development (RD). The control variables import and export intensity, the human development indicator and the intensity of technical cooperation improved between 1998 and 2004, but we observe some variation among the OECD countries, although it is smaller than that of the innovation performance variable. The development of the indicators representing the regulatory environment is not homogeneous. Only the competition and the IPR regulation improved between 1998 and 2004, whereas price, product, environmental and the general legal framework conditions worsened slightly – after some improvements until 2002. Wölfl et al. (2009) also observe signs of fatigue in regulatory reforms by OECD countries. Finally, the variance in the assessment differs significantly with a more homogeneous situation in the case of environmental regulation, whereas the variance is much larger in the IPR regulation and the general regulatory framework conditions.

3.2. The methodology

In order to reflect the theoretical model elaborated in Chapter 2, we are not using simple cross-country data, but panel data, which allows us to test for dynamic causalities, i.e. the influence of regulation on innovation, but unfortunately not for feedback loops. Using panel data in general poses the problem that time series follow a trend. Since especially the innovation indicators are increasing over time, we use the first differences for all variables to run the regression. As estimation approach we apply not ordinary least squares regression, but a weighted least squares regression with fixed effects, taking into account the different sizes and levels of economies, but also any unobserved heterogeneity across countries in unmeasured determinants of patenting activity, like different patenting cultures. This leads to the following equation:

$$\Delta \mathrm{PATINT}_{rit} = a_i + b^* \Delta \mathrm{RD}_{it} + c^* \Delta \mathrm{IMP}_{it} + d^* \Delta \mathrm{EXP}_{it} + e^* \Delta \mathrm{HDI}_{it} + f^* \Delta \mathrm{TEC}_{it} + g^* \Delta \mathrm{REG}_{rit} + u_{it}$$

with regulation $r = 1–6$, country $i = 1 \ldots 21$ and time $t = 1999–2004$.

4. Results of the regression analyses

In this section, we present and discuss the results of the regression analysis. The results of the six regressions are summarized in Table 5. In general, the performed regression analysis overall has a rather similar explanatory power of an adjusted R^2 of around 0.30 regarding the depending variable. The positive exception is the model including the quality of the enforcement of IPR with an R^2 of more than 0.35, whereas the model including the general legal framework conditions achieves only an R^2 of around 0.16. Five out of the six regulation indicators reach very high levels of significance. Only the changes of the assessment of the efficiency of the competition legislation to prevent unfair competition are not significant for the explanation of the innovation performance of OECD countries with a negative coefficient. Two framework conditions, i.e. product and service legislations and environmental laws and compliance, have a negative influence on the countries' innovation performance. Non-restrictive price regulations, an efficient enforcement of IPR and a legal and regulatory framework encouraging the competitiveness of enterprises are positive for innovation performance.

Before we discuss these heterogeneous results in detail, we will first examine the influence of the control variables. Changes in the R&D intensity have both positive and negative influences on the innovation output of countries but these are not significant. An explanation for a missing significant positive relationship can be a disentangling between R&D and patent developments partly driven by strategic motives to patent (Blind et al., 2006) and possible increases in research productivity (Kortum and Lerner, 1999). Import intensity has no significant and a rather negative influence in all models, which does not confirm the hypothesis of competitive pressure from abroad on domestic innovators. In contrast, the impact of the export intensity is significantly positive in all six regressions. Obviously serving customers from abroad and the degree of openness of an economy are positive for innovation. The Human Development Indicators reflecting both more demanding domestic customers and a better educated work force are highly influential for the innovative performance of OECD members countries included in the study. Finally, improvements in the degree of technical cooperation between companies have a positive influence in all models – but significantly in only two – on the innovative performance of economies. In summary, the control variables reflecting the most crucial factors for the innovative performance of an economy mostly have the expected positive and significant influence on innovation in OECD countries. R&D and the import intensity are the exception.

This section gives a detailed discussion of the results of the impacts of the six regulatory framework conditions on the innovation performance of OECD countries. We start with competition legislation, which is efficient in preventing unfair competition but has no significant positive influence on innovation. This result reflects the tension between two contradicting forces. On the one hand, many mainstream economists argue that companies are under to pressure to innovate with efficient competition. On the other hand, empirical evidence (Aghion et al., 2005) shows that if competition is too fierce the incentives to innovate and – going back to Schumpeter – the available resources are reduced. Therefore, the insignificant influence of legislation ensuring fair competition reflects these two controversial arguments indicating that

Table 5
Results of separate regression analyses explaining patent intensity.

	COMP	PRICE	PRODUCT	ENVIR	IPR	LEGAL
ΔREGi	0.1057	1.3466***	−2.4520***	−1.1757***	1.4473***	0.7376**
ΔRD	5.2151	−1.3757	2.7322	8.6444	2.8534	−0.5753
ΔIMP	−0.1609	−0.2071	−0.0434	−0.1605	−0.1899	−0.1893
ΔEXP	0.92920**	1.0705***	0.7857***	0.8969**	0.9495**	0.8988*
ΔHDI	629.68***	554.89***	638.47***	665.39***	521.11***	527.58***
ΔTEC	0.3236	0.0546	0.7036***	0.5282	0.2881	1.0203**
Adjusted R^2	0.315	0.322	0.298	0.284	0.354	0.161
Observations	126	126	126	126	126	126

Sign. level: ***<0.01; **<0.05; *<0.10.

Schumpeter's inclination towards monopolistic markets structures promoting innovation is obviously in line with reality.

In contrast, a regulation of prices in the way that the price setting of companies is not affected is obviously very positive for a country's innovative performance. A regulatory framework does not hinder companies from setting their prices to allow maximized profits, which is both an incentive to innovate and also provides the resources for future investment in innovation related activities. This again confirms Schumpeter's argumentation.

At first glance, a surprising result is the positive influence of product and service legislation, which deters business activity, on a country's innovative performance. On the one hand, this result contradicts the argument that public interventions reduce incentives and resources to innovate. On the other hand, public intervention can also stimulate innovation activities, as postulated in the Porter hypothesis (Porter and van der Linde, 1995) in the case of environmental regulations. Furthermore, public support for R&D and innovation activities may also "deter" business activities in the sense that innovation supporting activities often direct companies into investments in future technologies and prevent them from protecting old production processes or outdated product portfolios. Finally, increasing support for this statement may indicate a shrinking influence of government as such, which also includes its innovation stimulating role.

As already mentioned in the previous section, the Porter hypothesis argues that environmental regulations can create incentives for the development of new eco-friendly processes and products including environmental technologies. In the short run, companies may feel hindered in achieving their competitiveness. However, in the medium and long run, the efforts to comply with challenging environmental regulations lead to an increase of international competitiveness if these so generated innovative technologies are accepted due to the adoption of the same environmental regulations in other countries or due to enhanced resource or energy efficiency requirements making these products and technologies more attractive. In summary, this regression result impressively confirms Porter's hypothesis for OECD countries as a whole.

Institutional regulations which ensure that intellectual property rights are adequately enforced obviously fully confirm the theoretical consideration of Carlin and Soskice (2006), but also similar previous empirical studies, like Koch et al. (2004), who find a positive influence of IPR regulations on the R&D intensity of the former G7 countries.

Finally, a general legal and regulatory framework encouraging the competitiveness of enterprises in OECD economies also promotes their innovation performance, which is in line with the results of OECD studies (Bassanini and Ernst, 2002; Conway et al., 2005).

In addition to the separate regression equations, we also conduct a regression including the five specific regulatory framework conditions. We do not include the general legal framework conditions, due to their high correlation with the five specific regulation indicators. In general, the result of this comprehensive model confirms the separate regression results. However, the price and product regulations lose their significant influence due to high correlation with the other indicators, whereas insufficient competition legislation has a positive influence on the innovation performance of the OECD countries included in this study[3] (Table 6).

Table 6
Results of the comprehensive regression analysis.

ΔRD	2.6604
ΔIMP	−0.3119
ΔEXP	1.1478***
ΔHDI	511.6835***
ΔTEC	0.7152**
ΔCOMP	−1.6287***
ΔPRICE	0.6676
ΔPRODUCT	−0.5092
ΔENVIR	−1.5656***
ΔIPR	1.6078***
Adjusted R^2	0.192
Observations	126

Sign. level: ***<0.01; **<0.05; *<0.10.

Although we can find explanations for the empirical results related to the separate influence of the different regulatory framework conditions, it is not obvious to construct a consistent rationalization in a comprehensive conceptual approach. In the final section, we bring together the puzzling empirical results to give a consistent picture and give an outlook on future research.

5. Discussion and outlook

In general, the modifications in selected regulatory and legal framework conditions have a significant influence on the dynamics of the innovative performance of OECD countries measured by the intensity of world patent applications. On the one hand, we observe contradictions between the positive influence of general legal and regulatory framework conditions encouraging competitiveness, an efficient regime enforcing IPR and unrestricted price setting. On the other hand, we see a positive impact of product and service legislation deterring business activities in general, and environmental laws and compliance hindering competitiveness in particular.

The former group has positive implications for the Schumpeter relation, i.e. it provides additional incentives for investments in R&D including allowing temporary monopoly positions via patents and maximizing profits without price restrictions. Consequently, these results confirm our theoretical approach. Competition

[3] To check the influence of regulatory framework conditions on business investment in research and development (RD), Table A in the Annex shows the results of the six regression results. However, only the directly related IPR regulations and the general regulatory framework conditions have the expected significant positive influence. All other regulatory indicators have no significant influence due to rather untied causal links.

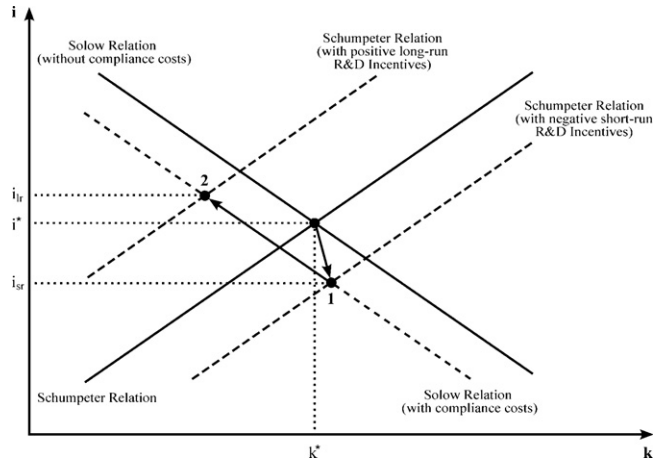

Fig. 3. The influence of regulation on the endogenous determination of innovation in the short and long run.

enhancing regulations have no decisive impact, because there is no clear shift of the Schumpter relation. Assuring a high level of competitiveness might increase the incentives to innovate, but if competition intensity is too high, the original positive relation might change into a negative one and in the long run, Following Schumpeter's argument, the resources for future innovation activities might be not available.

Product and service legislation including environmental laws, which deter business activities and reduce their competitiveness, incur compliance costs for companies and consequently shift the Solow relation to the left and possibly the Schumpeter relation to the right. Both these shifts should lead to a lower innovation level i_{sr} – at least in the short run (see point 1 in Fig. 3). However, governmental intervention can direct companies' activities into future technological areas and emerging markets, which are characterised by much higher R&D incentives leading to a strong rightward shift of the Schumpeter relation and consequently to a higher innovation level i_{lr} in the long run (see point 2 in Fig. 3).

The distinction between short-run and long-run impacts of regulation on innovation allows us to solve the puzzle of a positive influence of product and service legislations including environmental laws, which deter business activities and reduce their competitiveness.

These analyses provide new insight into the influence of various regulatory framework conditions on innovation. The simple transfer of this approach to explain the business expenditures of OECD countries on R&D reveals that besides the IPR regime, obviously other regulatory framework conditions are relevant, which have not been considered in this paper. Consequently, this represents a further challenge for future research. Besides expenditures on R&D, the foundation of new enterprises is another indicator for innovation and consequently a driving force for growth. Here, additional regulatory framework conditions focusing on setting up new enterprises have to be considered. Furthermore, more objective indicators characterising the regulatory framework conditions have to be taken into account, such as the set of OECD indicators recently presented by Wölfl et al. (2009). Finally, the interplay between regulatory framework conditions is decisive for their overall impact on innovation. For example, regulatory activities focused on the R&D activities in a specific technological area have to be coordinated and timed with regulations fostering the demand side. This can be done either by increasing the purchasing power via subsidies for new products or by promoting their acceptance through safety regulations which take into account new emerging risks.

So far, the analysis has not taken taken into account the increasing regional coordination of the regulatory framework activities, e.g. within the European Union, or international, especially in the case of climate policy. Such a convergence will have also implications for the national innovation activities. If the international coordination increases the requirements significantly, especially the lagging countries have to invest more, also in innovation, to meet them. However, if the outcome of such international negotiations is more a minimal compromise the pressure to innovate will be reduced. Finally, especially the global regulatory efforts will have strong implications on the non-OECD countries, which deserve future research efforts.

In addition to including further explanatory variables and relevant regulatory framework conditions, the dependent variable has to be differentiated and adapted to the specific regulatory framework conditions. For example, focusing on environmental regulations requires the use of special indicators reflecting innovation in environmental technologies, products and services.

Finally, it should be noted that the regulatory framework is also influenced or pressurised by progress in science and technology, and is therefore – at least in the long run – an endogenous and not an exogenous factor in the innovation system. This dynamic dimension represents a further challenge both for future research and for regulatory and innovation policy.

All the varied and complex dimensions which are required for the successful use of the regulatory framework to promote innovation clearly show that this relationship represents a great challenge for the future development of theoretical concepts and analysis, empirical investigations and practical policy implementation.

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Appendix A. Additional regressions

Table A1

Table A1
Results of separate regression analyses explaining R&D intensity.

RD	COMP	PRICE	PRODUCT	ENVIR	IPR	LEGAL
ΔREG	−0.0163	0.0255	−0.0246	−0.0373	0.0895**	0.2182***
ΔIMP	0.0425***	0.0424***	0.0416***	0.0408***	0.0320**	0.0402***
ΔEXP	−0.0037	−0.0028	−0.0018	0.0005	0.0029	−0.0109
ΔHDI	−19.2136***	−27.2261***	−15.0457***	−23.1206***	−24.4146***	−31.4799***
ΔTEC	−0.14096***	−0.1368***	−0.1858***	−0.1205***	−0.1987***	−0.0630*
Adjusted R^2	0.163	0.239	0.115	0.229	0.147	0.297
Observations	126	126	126	126	126	126

Sign. level: *** <0.01; ** <0.05; * <0.10.

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