

Erken, Hugo; van Es, Frank

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Disentangling the R&D shortfall of the EU vis-à-vis the US

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Disentangling the R&D shortfall of the EU vis-à-vis the US

by

**Hugo Erken
Frank van Es**

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www.econ.mpg.de

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Disentangling the R&D shortfall of the EU vis-à-vis the US

August 2007

Hugo Erken

Ministry of Economic Affairs and
Erasmus University

Frank van Es

CPB Netherlands Bureau for Economics Policy Analysis

Abstract

This paper investigates the causes of the shortfall in private R&D expenditure of the EU compared to the US. It shows that differences in the structure of the two economies play only a minor role in explaining the R&D gap. Instead, the European R&D shortfall is mainly caused by a negative intrinsic effect, meaning that companies within European industries spend less on R&D than their US peers in the same sectors. In addition, this negative intrinsic effect is mainly due to institutional differences between the US and the EU15. Government funding of R&D and the internationalization of R&D provide significant explanation as well.

JEL-classification: O32, O38, F23, R39

Keywords: private R&D intensity, internationalization of R&D,
economic structure, sector-composition effect, intrinsic effect

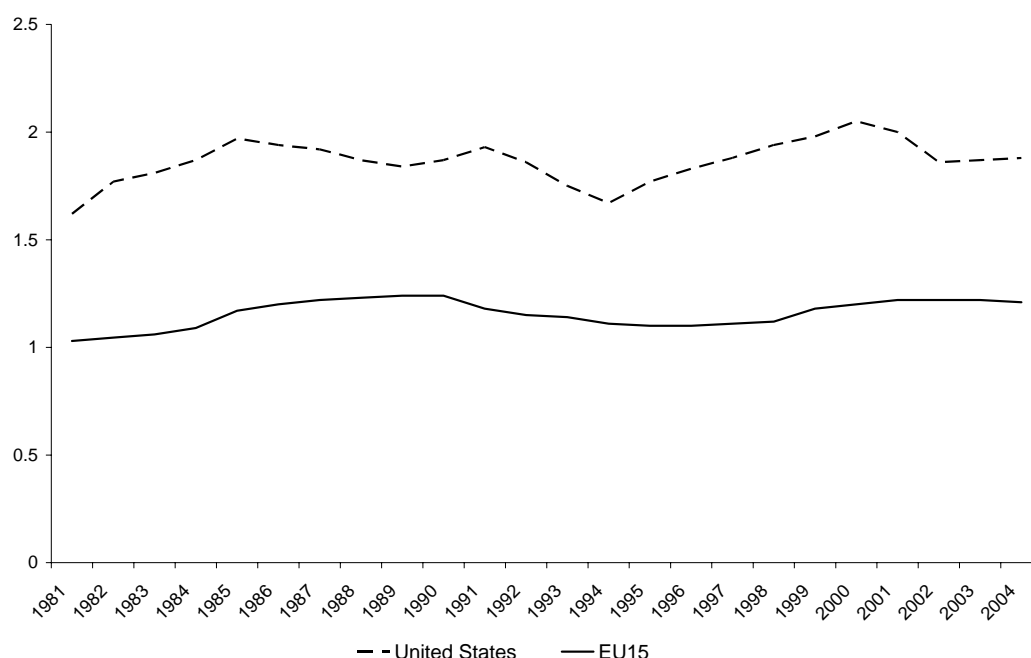
Acknowledgement: We would like to thank Vincent Duchêne of the European Commission and Pauline de Jong of the EIM, as well as Luuk Klomp, Stephan Raes and Arie van der Zwan of the Dutch Ministry of Economic Affairs for their assistance and valuable comments on earlier versions.

Contact: Hugo Erken, Ministry of Economic Affairs, PO Box 20101,
2500 EC The Hague, The Netherlands, h.p.g.erken@minez.nl

1. INTRODUCTION

It is broadly accepted that business research and development (R&D) is an important engine for productivity growth (e.g. Baumol, 2002; Jones, 2002). The European Union lags considerably behind the US in this respect (see Figure 1). European political leaders recognise the importance of R&D to meet future economic challenges and consequently formulated two major innovation and R&D objectives. The first is the ‘Lisbon ambition’, in which the EU aims to become the most dynamic and competitive knowledge economy in the world by 2010. The second (and more specific) policy objective is the ‘Barcelona target’, which commits the EU to raise its R&D expenditure to 3% of GDP, two thirds of which should be financed by the private sector (European Council, 2002; European Commission, 2002). Within the context of these European policy objectives, the R&D gap should be narrowed significantly.

Figure 1. Private R&D expenditures as a percentage of GDP



Source: OECD, Main Science and Technology Indicators, 2006-2.

The causes of the private R&D shortfall of the European Union vis-à-vis the US merit further investigation. Even if the deficit were mainly intrinsic, it would be difficult to improve the R&D performance of the EU using many of the well-known instruments. If the sector composition of the economy plays a major role in explaining the R&D gap between the EU and the US, however, the policy debate concerning how to narrow the existing R&D deficit would be even more complicated. Although the sector composition of a country is not completely exogenous, such a situation would require even greater effort and more time to enhance the intrinsic R&D position of the EU15 in order to catch up with US R&D standards.

This paper uses the methodology developed by Erken and Donselaar (forthcoming) to disentangle differences in business R&D between countries or regions. The structure of this paper is as follows. In Section 2, the R&D gap between the EU15 and the US is broken down into a sector-composition effect and an intrinsic effect. Section 3 discusses the causes of the intrinsic R&D shortfall of the EU relative to the US. In Section 4, we provide an overall decomposition of the private R&D shortfall in the EU15 vis-à-vis the US.

2. SECTOR COMPOSITION EFFECT AND INTRINSIC EFFECT

When comparing the R&D intensity between the EU15 and the US two effects should be taken into consideration: a *sector composition effect* and an *intrinsic effect*. The *sector composition effect* compares the share of knowledge-intensive industries within the overall economic structure between countries or regions. If the share of knowledge-intensive industries within the total economy of Country X is larger than it is in country Y , the sector composition effect is positive for Country X and negative for Country Y . The *intrinsic effect* is the complement of the sector composition effect and represents the within-industry effect. A negative intrinsic effect implies that companies within a given industry spend less on R&D than their foreign counterparts in the same sector.

Formula (1) is used to calculate both effects (see Van Velsen, 1988; Hollanders and Verspagen, 1998, 1999; Erken and Donselaar, forthcoming):

$$RDI_X - RDI_Y = \sum_i RDI_{Y,i} (P_{X,i} - P_{Y,i}) + \sum_i P_{X,i} (RDI_{X,i} - RDI_{Y,i}) \quad (1)$$

In equation (1), RDI represents the extent of private R&D intensity (measured by expenditures on R&D as a percentage of the gross value added), P stands for the share in the value added, i indicates the sector; X and Y stand for country/region X and the countries/regions with which country X is compared, respectively. In our calculations, the weighted EU15 average represents Country X and the US (Country Y).¹ The *sector-composition effect* is the first term after the equals sign, and the *intrinsic effect* is the term after the plus sign.

Industry data on value added and R&D expenditure are taken from the GGDC 60 Industry Database, the OECD STAN database and the OECD ANBERD database. The data were configured by the Dutch Ministry of Economic Affairs. The dataset used for this paper covers the following:

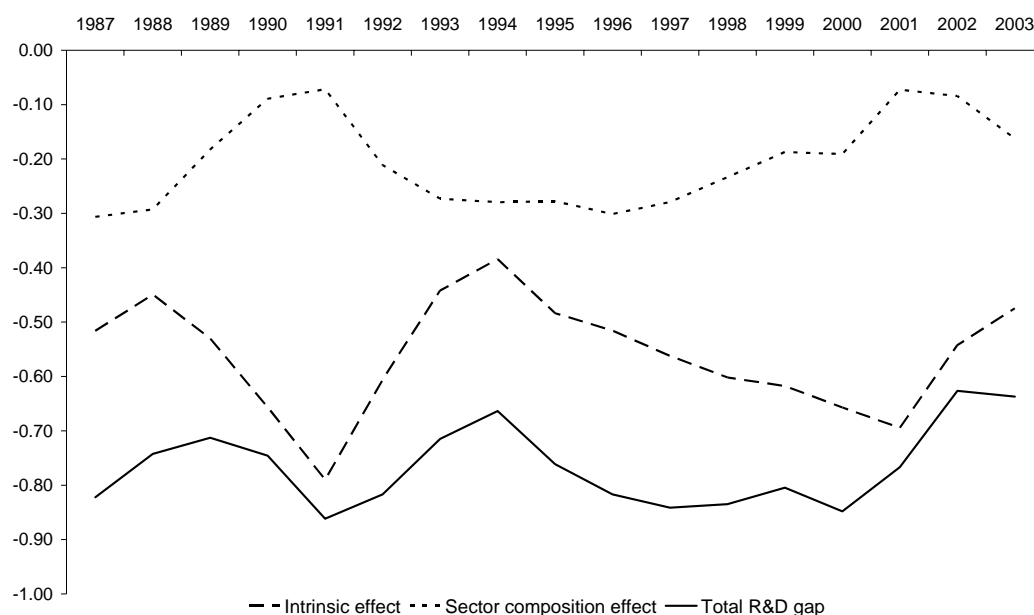
- 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, the UK and the US
- 36 industries
- The period 1987-2003, i.e. 17 years

¹ Unless otherwise mentioned, the weighted EU averages in this paper are based on value added shares.

In Figure 2, the difference between the US and the EU15 in terms of business R&D is broken down into a *sector composition effect* and an *intrinsic effect*. This paper considers the private R&D gap between the US and the EU15 in 2002. The total R&D gap presented in Figure 2 deviates slightly from the total R&D gap plotted in Figure 1. The difference in business R&D intensity between the EU15 and the US is 0.74 percentage points based on data from the Main Science and Technology Indicators, whereas calculations based on the OECD STAN, OECD ANBERD and GGDC data show a difference of 0.63 percentage points. This difference arises from the fact that gross value added is expressed at basic prices in the industry-level calculations (i.e. Figure 2), whereas the gross domestic product at market prices was used as a denominator for the private R&D intensity in figures based on data from the OECD Main Science and Technology Indicators (Figure 1).

Figure 2 shows that differences in the sector composition of Europe and the US provide only a marginal explanation for the R&D divergence between the two countries. In 2003, the sector composition was responsible for roughly 25% of the total R&D shortfall of the EU vis-à-vis the US. The remaining 75% of the European R&D gap is intrinsic in nature.

Figure 2. Difference in private R&D intensity between the EU15 and the US (EU15-US), 1987-2003



Source: Authors' calculations based on the OECD ANBERD and STAN databases and the GGDC 60-Industry Database.

Breaking down the R&D difference between individual EU countries and the US results in a more differentiated picture. Some countries do show a strong sector composition effect (either positive or negative), while other countries reveal no effect. Furthermore, the sector composition effect is quite volatile over time in some cases. Because the

differences between countries equal out at the aggregate level, however, we can conclude that the size of the sector composition effect for the EU as a whole is limited.

Just as is the aim of this paper, the European Commission (2007) has recently conducted a study to gain more insight into the causes behind the R&D funding gap between the European Union and the US. The Commission states that with regard to the manufacturing sector (pp. 28 and 29): '*structural differences seem to be at least as important as the 'intrinsic effect' (i.e. sector-specific R&D intensities)*'. This finding is in accordance with our own calculations: within manufacturing the knowledge-intensity of industries (e.g. R&D intensity) does not seem to differ much between the US and the EU. Rather, the larger size of especially the US' ICT sector explains the difference in R&D expenditure between the manufacturing sectors in the US and the EU.

The European Commission, however, disregards the service sector in their analysis, because of comparability problems with R&D data of the services sector between the US and the EU (European Commission, 2007, p. 22). Based on work by the OECD (2005) and the National Science Foundation (2005) on differences in the methods used in the US and the EU to classify R&D by industrial activity, the Commission stipulates that there are much statistical drawbacks that complicate international R&D comparisons on an industrial level. The European Commission (2007, p. 24, footnote 14) estimates that at least 33% of the private R&D intensity in the services sector within the US is misallocated and instead should be ascribed to the manufacturing industry.

Despite the severity of these statistical drawbacks, there is no valid argument to ignore the service sector entirely. First of all, a sector composition analysis is not complete when the services sector is excluded. Most important, even if 33% or more of the private R&D expenditure in the US' service sector is wrongly allocated, there still remains a large intrinsic gap between R&D in the European services sector and the services sector in the US. In addition, reallocating R&D expenditure from US' services to the manufacturing sector would only marginally alter the picture sketched by Figure 2. Indirectly, the negative sector composition effect of the EU vis-à-vis the US would become slightly higher, which can be derived from equation (1). Because of relatively small sector composition differences in the manufacturing sector between the EU and the US ($P_{EU,i} - P_{US,i}$), combined with a higher R&D intensities of the individual industries in the US ($RDI_{US,i}$), the negative sector composition effect would rise somewhat. At the same time, the redistribution of R&D expenditure from the services sector to manufacturing would result *for the larger part* in a relocation of the negative intrinsic effect from the services sector to the manufacturing industry. The most important negative side effect of the statistical drawbacks is therefore that the specific sectors causing the total negative intrinsic effect are not known. In any case, after reallocation of R&D investments from the US' services sector to the manufacturing sector, the EU15 would still cope with a large negative intrinsic effect and a relatively limited negative sector composition effect.

The weak explanatory power of the sector composition effect implies that, in general, the European Union cannot ascribe its poor R&D position to factors that are largely

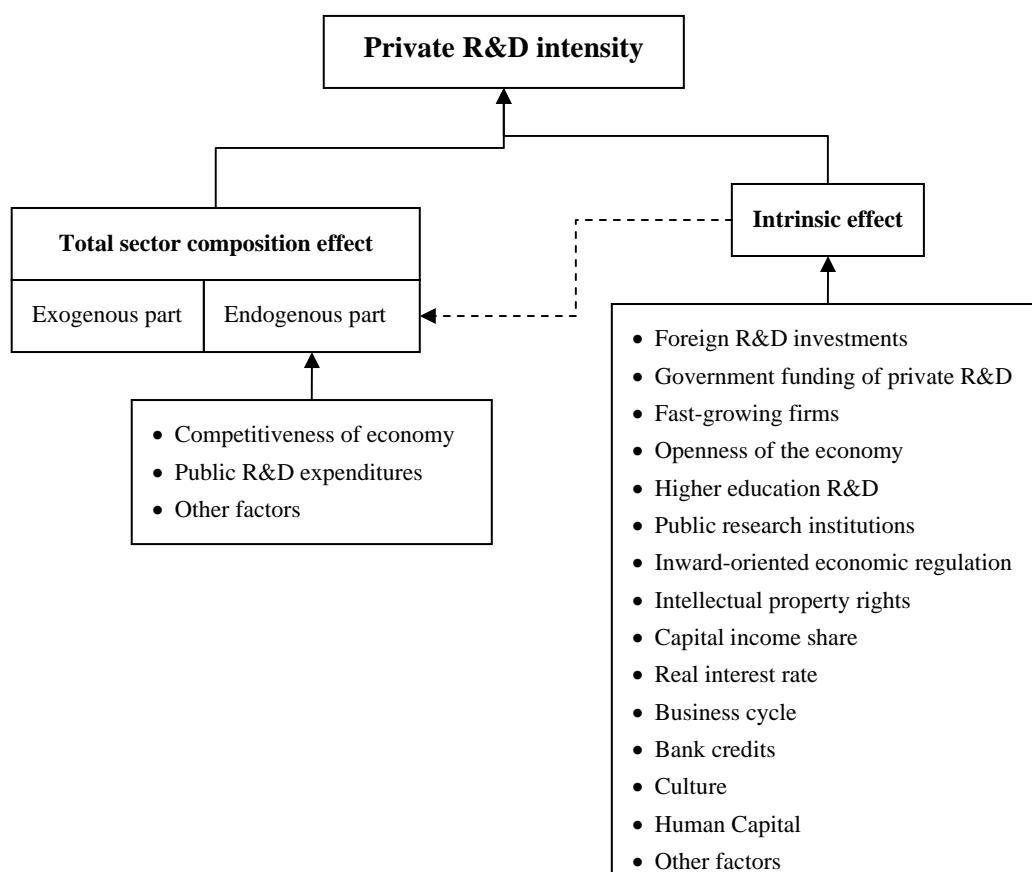
exogenous in the short term (i.e. the structure of the European economy). The intrinsic effect is clearly more sensitive to governmental policy than the sector composition effect is. This is apparently good news for policymakers. The following section considers the elements of the intrinsic effect along which the EU generally lags behind the US.

3. DISENTANGLING THE INTRINSIC EFFECT

3.1 *Theoretical framework and methodology*

In the previous section, we showed that the R&D shortfall of the EU15 vis-à-vis the US can be largely attributed to the negative intrinsic position of the EU15. In this section, we elaborate on possible causes of this negative intrinsic effect. A country's intrinsic position depends upon a large spectrum of determinants (e.g. the intensity of internationalisation that a country is facing with regard to R&D, the institutional environment and the level of government support for stimulating business R&D). Figure 3 shows a theoretical framework of the determinants of private R&D from a macro level of perspective.

Figure 3. Theoretical framework of the determinants of private R&D



The figure shows that total private R&D intensity in a country is dependent on both the sector composition effect and the intrinsic effect. The sector composition itself is not completely exogenous and is partly dependent on the intrinsic effect itself (see for more information on this relationship Erken and Donselaar, forthcoming). This implies that the technological competitiveness of a country is reflected in its economic structure.² A positive sector composition effect is not, or at least not solely, the consequence of more or less coincidental and historically determined circumstances, but the result of successful competition on technology markets.

In empirical analyses, the effects of determinants on the intrinsic effect are generally estimated by an econometric analysis, which often has the following functional form:

$$RD_{i,t} = \alpha_i + \beta_i X_{i,t} + \delta_i D_{i,t} + e_{i,t} \quad (2)$$

In equation (2) $RD_{i,t}$ represents the R&D intensity of countries, firms or industries (i) at time t . $RD_{i,t}$ is modelled as a function of a constant term α_i , explanatory variables $X_{i,t}$ and a vector of dummy variables (firm-, country- or industry-specific fixed effects) $D_{i,t}$. The error term is denoted by $e_{i,t}$. If equation (2) is estimated at the macro level, it is important to include the sector composition effect as a separate variable within vector $X_{i,t}$. On lower levels of aggregation, the impact of the sector composition effect is irrelevant. If the sector composition effect is properly accounted for, $X_{i,t}$ embodies the various mechanisms that influence the intrinsic effect, e.g. foreign R&D investments, government stimulation of R&D and institutions.

Because there is no research available which studies the impact of all determinants of private R&D simultaneously, we adopt a ‘partial approach methodology’ or eclectic approach to break down the intrinsic effect between countries. The eclectic approach adopted in this paper unfortunately does have a number of disadvantages. For example, the elasticities between studies that examine the impact of particular determinants of business R&D vary and are not always consistent. As a consequence, a certain level of uncertainty accompanies any partial quantification based on these elasticities. To obviate the problem of arbitration as much as possible, Erken and Donselaar (forthcoming) conducted an assessment of the empirical literature dealing with the determinants of business R&D. This assessment led to a selection of studies that are considered to provide the most reliable insights into the impact of various determinants on private R&D expenditure. With regard to certain determinants, however, the literature remains scarce and complicated.

To bridge these empirical gaps, we use results from an empirical study by Donselaar and Segers (2006) (which was carried out parallel to the study by Erken and Donselaar), in which the impact of many determinants of business R&D has been examined in a simultaneously-estimated model. The study uses panel data covering 20 OECD countries over a period of 31 years. A major benefit of the study by Donselaar and Segers is that so-

² Besides the impact of the intrinsic effect on the sector composition effect, the influence of public R&D and price competitiveness was made explicit in the model by Erken and Donselaar.

called *omitted variable bias* is limited, because their model contains many variables (more than most other empirical studies explaining business R&D). Omitted variable bias means that when an explanatory variable ($X1$) is omitted from an econometric specification and correlates with both the dependent variable and a variable that is included in the specification ($X2$), the coefficient of $X2$ is biased (e.g. Wooldridge, 2003, pp. 89 ff; Verbeek, 2004, pp. 55 ff).³ An example of this problem for our decomposition analysis is the effect of the *business cycle* on the R&D intensity (see Section 3.8). Because $X1$ (in this case *profitability*) is correlated with both $X2$ (*business cycle*) and the R&D intensity, the effect of the *business cycle* is biased when *profitability* is omitted from the econometric specification. We indeed observe that the coefficients estimated by Donselaar and Segers represent effects that are more moderate than those found in other studies that estimate less-advanced models.

There are still some factors determining the intrinsic effect that are hardly dealt with in the empirical literature, e.g. the impact of culture, the availability of human capital and the size of countries.⁴ The determinants were necessarily omitted in this paper, because of either data problems or contradictory empirical evidence. For example, the impact of human capital on R&D expenditure is insignificant in most empirical studies (see Kanwar and Evenson, 2001; Reinthaler and Wolff, 2002).⁵ Because we could not include all determinants of private R&D in this study there could be some overestimation or underestimation of the intrinsic shortfall of the EU, which would have consequences for the overall decomposition of the R&D gap. Nevertheless, we believe that most of the important factors of private R&D intensity have been included in this study, allowing us to provide a fairly clear picture of the causes behind the observed R&D shortfall of the European Union in 2002. Further research is needed to expose the importance of the omitted determinants of business R&D.

Another disadvantage of the partial approach is that it does not take into account the interaction effects between determinants that have a multiplicative relationship with business R&D. In Annex 1, we performed a test to examine the possibility of significant interaction effects between these determinants. The results show that the sum of the interaction effects between determinants that have a multiplicative relationship with business R&D are quite low (0.01 percentage point in total). This interaction effect is included in the overall decomposition in Section 4.

³ The coefficient is overestimated in case of positive correlation and underestimated in case of negative correlation.

⁴ For example, Van der Horst *et al.* (2006) show that large countries (in terms of GDP) spend more on public R&D than small countries do. The same counts for public funding of private R&D, although there is apparently no relation between the public funding of innovative SMEs and the size of the economy.

⁵ A study by Reinthaler and Wolff (2002) finds an insignificant effect of human capital (i.e. the share of highly educated persons within the total population) in a fixed-effects model and a model with random effects. In estimations of a model without fixed effects, the researchers do find a significant effect of human capital, indicating that human capital arguably could have a positive effect on R&D in the cross-sectional dimension. Panel data estimations without fixed effects are vulnerable to estimation bias, however, because of possible unobserved heterogeneity (Wooldridge, 2003, p. 439; Popkowski Leszczyc and Bass, 1998). We must therefore interpret these empirical outcomes with some caution.

Despite the shortcomings of the applied partial approach, we believe that it is the best methodology available for breaking down the intrinsic R&D differences between countries or regions. The remainder of Section 3.1 is as structured as follows. In Sections 3.2 till 3.4, we examine the contribution of determinants that have an additive relationship with business R&D. In the Sections 3.5 to 3.8, we address the drivers of business R&D that show multiplicative relationships, (e.g. the openness of the economy and inward-oriented economic regulation). The partial contribution of each determinant is incorporated in the decomposition table of Section 4.

3.2 *Internationalisation of R&D*

In analysing the effect of internationalisation of R&D activities on the R&D gap between the EU and the US, two types of R&D flows should be taken into consideration: outward and inward R&D investments. Outward investments encompass investments flowing from the home country to a host country.⁶ Inward investments represent the opposite.⁷ The OECD *Activities of Foreign Affiliates* (AFA) database provides data on inward and outward R&D flows. The availability of data in the outward R&D database is low, however, complicating its ability to be used to determine the role of outward R&D as an explanation for the R&D funding gap between the US and the EU15. In contrast, the inward R&D database does provide sufficient data for this purpose.

The AFA database contains data on the inward R&D investments of nine EU15 countries: Germany, Finland, France, Ireland, the Netherlands, Portugal, Spain, Sweden and the UK. These countries account for over 80% of total R&D expenditure in the EU15. This subset of countries therefore sufficiently represents the R&D expenditures of foreign affiliates in the EU15. The inward R&D investments of the EU cannot simply be determined by taking the sum of the inward R&D investments of the nine individual EU countries. These investments include investments between EU countries, which should not be considered as inward R&D investments of the EU15 as a whole. We must therefore adjust total inward R&D investments of the EU for these ‘intra-EU investments flows’. This can be accomplished by considering only the inward R&D investments originating from non-EU countries (e.g. Japan, Canada and the US).

Unfortunately, no data are available about the origin of *total* inward R&D investments. The origin of the inward R&D investments in the *industry sector* can be used as an alternative. These R&D investments account for the larger part of all inward R&D investments; their origin can therefore be considered a good substitute for the origin of total R&D investments. From these data, we can derive that 52.4% of the sum of industry inward R&D in the nine countries originates from outside the nine EU countries. The sum of the *total* inward R&D investments of all nine countries is multiplied by 0.524 to adjust

⁶ Definition from the OECD (2004, p. 11): “For outward investment, in principle, the ultimate host country should be considered, but if it is difficult to identify it, the concept of “immediate host country” can be used”.

⁷ Definition from the OECD (2004, p. 11): “For inward investment, the geographical origin of the foreign affiliate corresponds to the home country of the parent company. In principle, the ultimate beneficial owner (UBO) should be considered, but given that some investments are carried out through holding companies or affiliates different from that in which the parent company is located, it is difficult to identify the initial investor. In this case, the country of origin is that of the ‘immediate controller’.”

for intra-EU R&D flows. The same method is applied for correcting the export and import data for the EU, which should be adjusted for the openness of the economy.⁸

The role of openness of the economy

Inward R&D investments are more important in small, open economies than they are in large, closed economies. In general, taking part in global trade is more important for small economies than it is for large ones. For example, studies by Alesina and Wacziarg (1998) and by Ales and Glaeser (1999) show that small economies are more open than large economies. We expect this to apply to the share of foreign R&D in total R&D investments as well. This share should thus naturally be higher in open (and small) economies than it is in relatively closed (large) economies.

In this paper, we use the indicator *exposure to foreign trade*, as developed by Bassanini *et al.* (2001, p. 25). Calculating this indicator involves taking the sum of the export intensity and the import penetration of each country.⁹ To account for the openness of the economy, we use the results of the econometric analysis by Erken and Donselaar (forthcoming). In this analysis the ratio of inward R&D investments as a share of domestic R&D investments is related to the trade exposure indicator from Bassanini *et al.* (2001) (see the paper by Erken and Donselaar for a more detailed description of this econometric analysis).

Contribution of inward R&D investments to the R&D gap between the EU and the US

Using this econometric analysis, we are able to determine the contribution of inward R&D investments to the R&D gap between the EU and the US. First, we ascertain how much foreign R&D investment the EU and the US should attract in order to reflect the openness of their economies. These ‘fitted values’ are represented by the solid line in Figure 4. The dotted lines represent surpluses and shortfalls in attracting foreign R&D by countries in 2001.

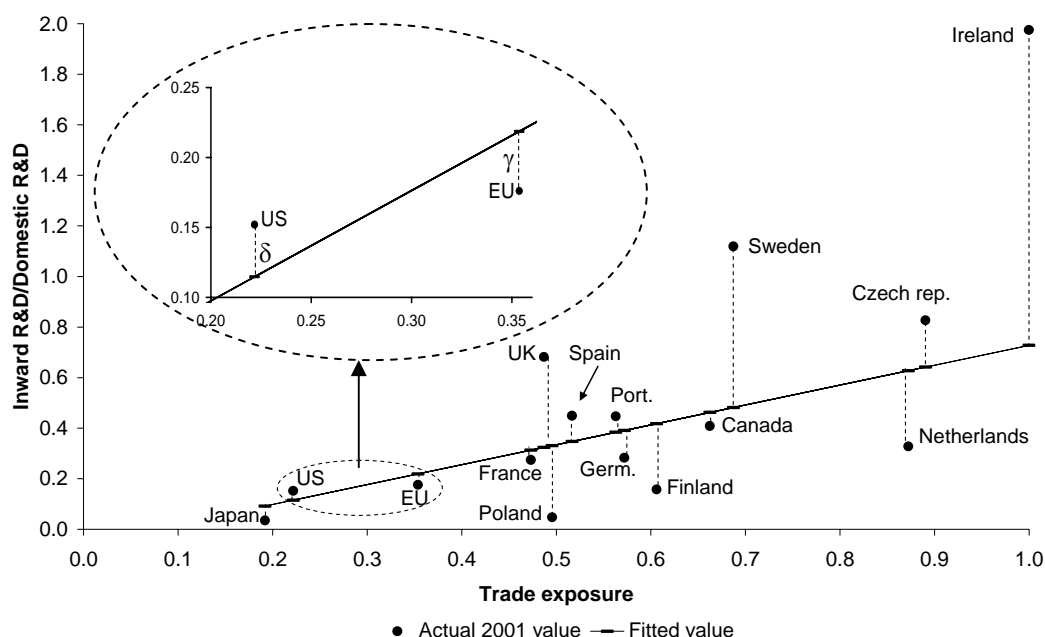
The ratio for the EU in 2001 (17.6%) was only marginally lower than the corresponding fitted value (21.9%). This means that, taking the openness of the economy into account, the EU attracted somewhat too little foreign R&D in relation to domestic R&D: 4.3 percentage points. For the US, the results are different: the fitted value from the regression was 11.5%, whereas the actual value in 2001 was 15.2%. The US attracted 3.7 percentage points more foreign R&D in relation to domestic R&D than could have been expected considering the openness of its economic structure.

The next step is to calculate the contribution of the shortfall and the surplus of inward R&D investments in respectively the EU and the US, in order to explain the private R&D gap between them (see Box 1).

⁸ With regard to exports and imports, the shares originating from outside the EU are 56.5% and 58.6%, respectively. Data for exports and imports are extracted from the Eurostat External Trade database.

⁹ The first term is the ratio of total exports to GDP. The second term is the ratio of total import to domestic sales (GDP + total imports – total exports) multiplied by the inverse of the export intensity.

Figure 4. Surpluses and shortfalls in the ratio of inward R&D relative to domestic R&D, 2001



Source: Authors' calculations based on the OECD AFA database, Main Science and Technology Indicators 2006-2, OECD Economic Outlook and the Eurostat External Trade database.

Summing up, 0.11 percentage point ($0.05 + 0.06$, the sum of γ and δ in Figure 3) of the R&D gap between the EU and the US can be explained by the relative shortfall and surplus of the EU15 and the US, respectively, in attracting foreign R&D.

Box 1. Contribution of inward R&D investments

In 2001, the inward R&D intensity in the EU was 0.21% ($100\% \times (\text{inward R\&D}/\text{GDP})$). This means that an increase of the ratio of inward R&D to domestic R&D from 17.6% to 21.9% would raise the inward R&D intensity to 0.26% ($\Rightarrow (0.219 / 0.176) \times 0.21$). In addition, the shortfall in foreign R&D investments in the EU has a negative effect on the total R&D intensity of 0.05 percentage points ($0.26\% - 0.21\%$), as compared to the other analysed OECD countries (illustrated by γ in Figure 3). For the US, the same calculations can be conducted. The actual foreign R&D intensity of the US was 0.26% in 2001; a decrease from 15.2% to 11.5% of the ratio of inward to domestic R&D investments would therefore result in a decline of the inward R&D intensity to 0.20% ($\Rightarrow (0.115 / 0.152) \times 0.26$). Given the openness of the US economy, the surplus of inward R&D investments ultimately had a positive effect of 0.06 percentage points on the private R&D intensity of the US (illustrated by δ in Figure 3).

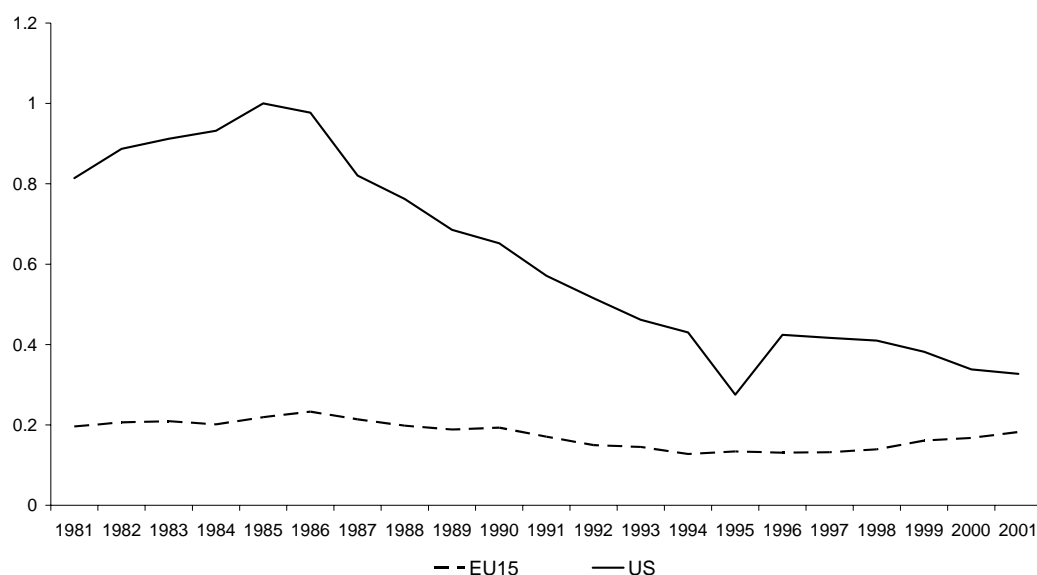
3.3 Government funding of private R&D

Business R&D can be funded by the government in two different ways (Guellec and Van Pottelsberghe, 2003). The government can finance business R&D directly by extending subsidies or R&D credits, or by placing R&D orders. Another way to stimulate business R&D is to provide R&D tax incentives.

The multiplier of government R&D incentives on business R&D can be fixed at 1.0 (see e.g. Hall and Van Reenen, 1999; Lichtenberg, 1984, 1987 and Scott, 1984). This means that one euro of additional R&D stimulation by the government – whether it embodies a R&D subsidy, fiscal R&D incentive or R&D order) – leads to one additional euro in R&D by businesses.

Data on the non-fiscal component of government funding of R&D is taken from the OECD Main Science and Technology Indicators. Data on international fiscal R&D incentives are derived from the OECD beta index (see Warda, 1996, 2002). Figure 5 shows the total government funding of R&D in the US and the EU15, expressed as a percentage of GDP in the period 1981-2001. These figures encompass all government funding of private R&D, including fiscal R&D tax incentives, as well as R&D subsidies/credits and R&D orders commissioned by the government (e.g. in the military industry). The plot clearly shows that, in 2002, the overall government funding of private in the US was higher than in the EU15. The shortfall in European business R&D consequently explains 0.14 of the total gap in European business R&D.¹⁰

Figure 5. Government funding of private R&D as a percentage of the GDP in the EU15 and the US, 1981-2001 (\$PPP, constant prices of 1995)



Sources: Authors' calculations based on data from the OECD beta index, the OECD Economic Outlook no. 74 and the OECD Main Science and Technology Indicators, 2004-2.

3.4 Fast-growing firms

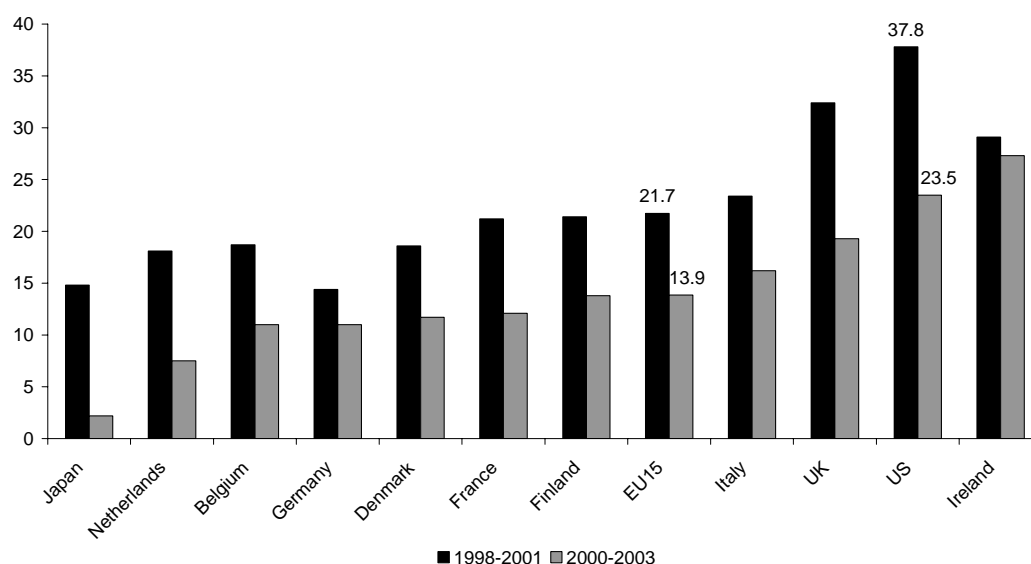
Fast-growing firms are more innovative than non-fast-growing firms. These 'gazelles' invest more in human capital, pursue a more active innovation strategy, introduce new products more often and spend higher amounts on R&D, relative to other firms. Baljé and Waasdorp (1999) estimated that fast-growing firms spend approximately 40% more on R&D as a percentage of their turnover compared to their non-fast-growing counterparts

¹⁰ Because of minor differences in rounding off, subtracting percentages in this paper does not always correspond to the presented percentage point difference between them.

(43% more on process development and 38% more on product development). Differences in the shares of fast-growing firms within total firm population of the US and the EU could therefore contribute to the European R&D gap between.

EIM reports annually on the prevalence of fast-growing firms as a share of total firm population (within the size class of 50-1000 employees). Data are available for Belgium, Germany, Denmark, Finland, France, Ireland, Italy, the Netherlands, the UK and the US. The data are presented over four-year periods. We use figures for the period 2000-2003, as this period includes the year 2002, which is the year of observation for our decomposition analysis. As shown in Figure 6, the share of fast-growing firms in the EU is lower than in the US (13.9% versus 23.5%).¹¹

Figure 6. The share of fast-growing firms with 50-1000 employees (% of all firms with 50-1000 employees), 1998-2001, 2000-2003



Source: Jong-'t Hart and Verhoeven (2007).

The calculations in Annex 2 illustrate that the R&D intensity in the EU would have been 0.03 percentage points higher if the share of fast-growing companies in the EU had been equal to that of the US.

3.5 *Openness of the economy*

In Section 3.2, we already addressed that the openness of the economy (in terms of openness to trade) has important implications for business R&D through the internationalisation of R&D. The openness of the economy also has an important direct effect on the level of private R&D expenditure (see e.g. Helpman, 2004; Falk, 2006). First, firms operating in open economies are more exposed to competition than firms in relatively closed economies. Because innovation is important to remain competitive, and

¹¹ The EU15 figure represents a weighted average based on the total number of fast-growing firms within the size class of 50 to 1,000 employees.

because R&D expenditure is one of the main drivers of innovation, it is reasonable to expect that more openness would lead to a higher level of R&D expenditure. For example, Smulders and Van de Klundert (1995) show that import competition encourages investments in R&D by simultaneously reducing mark-ups and increasing the level of domestic concentration. Second, a higher level of openness to foreign trade opens up possibilities to operate on larger export markets and exploit the results of R&D and innovation on a larger scale. Pires (2006) provides evidence that firms located in countries with more demand become more competitive because they have strong incentives to perform R&D.

The indicator for the exposure of countries to foreign trade is based on the previously-mentioned variable *exposure to foreign trade* (see Section 3.2). In line with Bassanini *et al.* (2001), we adjust this openness variable for country size. Small countries are more exposed to foreign trade than larger countries, regardless of their trade policies or competitiveness, because the share of small economies within total world economy is by definition smaller. In large countries, competitive pressure is due to domestic competition across regions. Annex 1 presents calculations on how to determine the contribution of openness to the R&D gap between the EU15 and the US.¹² We conclude that the openness to foreign trade contributes slightly positively to the intrinsic R&D position of the EU15 relative to the US (by 0.02 percentage points).

3.6 Public R&D

A country's level of public R&D expenditure has a direct influence on its private R&D expenditure. Public R&D is conducted by universities (Higher Education Expenditure on R&D: HERD) as well as public research institutes (Government Expenditure on R&D: GOVERD). A number of studies have examined the effect of public R&D intensity on private R&D intensity. Guellec and Van Pottelsberghe de la Potterie (2003) found a negative effect of public R&D expenditure on private R&D expenditure. This implies that public R&D expenditure could be a substitute for a country's private R&D expenditure. It is, however, more plausible that public R&D expenditure and private R&D expenditure are complementary (see European Commission, 2004; Reinthaler and Wolff, 2004; Falk, 2006). The most moderate effect is found in a study by Donselaar and Segers (2006).¹³

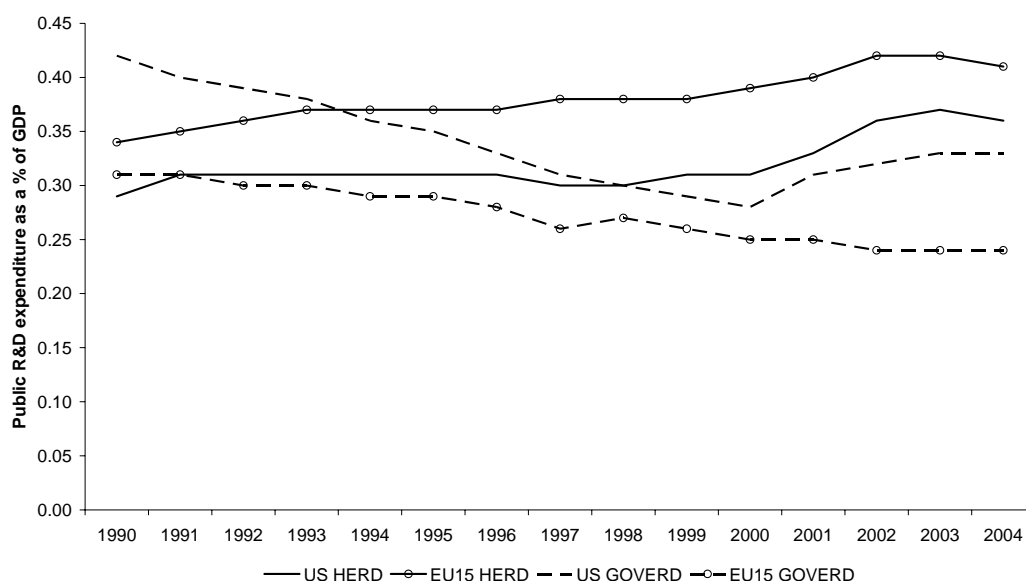
Data on public R&D spending was taken from the OECD Main Science and Technology Indicators (2006-2). Figure 7 shows the development of the HERD and GOVERD in the EU15 and the US. In 2002, the amount that universities spent on R&D (as a percentage of GDP) was lower in the US than it was in the EU (0.36% versus 0.42%), while the R&D expenditure of research institutes as a percentage of R&D was higher (0.32% versus 0.24%). By linking these differences in R&D intensity to the elasticities found by

¹² These calculations are based on the elasticity from Donselaar and Segers (2006), who adjusted their openness variable by using volumes and taking the relative size of the economy into consideration.

¹³ For example, the estimated effects of public R&D expenditure on private R&D expenditure by the European Commission are exceptionally high. The estimated coefficients imply that one additional euro spent on R&D by universities leads to an additional 1.3 euros in R&D expenditure by businesses. Similarly, one additional euro of R&D expenditure by research institutes results in an additional 1.1 euros R&D expenditure by the private sector.

Donselaar and Segers (2006), we are able to calculate the contribution of public R&D to the difference in private R&D between the EU15 and the US.¹⁴ The calculations in Annex 1 show that the higher R&D investments by universities in the EU15 had a marginal positive effect of 0.01 percentage point on the R&D intensity of the EU15 relative to the US. Conversely, the higher R&D expenditure of research institutes in the US contributes 0.05 percentage point to the private R&D funding gap.

Figure 7. Public R&D as a percentage of GDP, EU15 and OECD, 1990-2004



Source: OECD Main Science and Technology Indicators, 2006-2.

3.7 Institutions

Two important institutional regimes that appear to have an important impact on innovation and business R&D in countries are the intensity of product market regulation (e.g. state control, competition) and the rigorousness of the intellectual property rights (IPR) regime.

A hallmark study by Bassanini and Ernst (2007) examines the impact of product market regulation and IPR on private R&D intensity. As a part of total product market regulation, inward-economic regulation appears to be negatively correlated with business R&D, whereas a more stringent IPR regime shows a positive relationship with business R&D. These findings are in accordance with studies by Aghion *et al.* (2001) and Blundell *et al.* (1999): given a reasonable level of intellectual property right protection that limits the risk of imitation, competition has a beneficial effect on R&D and innovation. Bassanini

¹⁴ An estimate using private R&D intensity as the dependent variable results in a semi-elasticity of 0.47 for the effect of R&D by public research institutes (GOVERD) as a percentage of the GDP. In the same study, a semi-elasticity of 0.20 was estimated for the effect of university R&D (HERD) as a percentage of the GDP. These semi-elasticities can be transformed into multipliers. One additional euro spent on R&D by public research institutes adds 0.52 eurocents to the level of R&D expenditure by businesses, and one additional euro in R&D spending by universities increases in R&D expenditure by firms by 0.22 eurocents.

and Ernst (2007) report semi-elasticities of inward-oriented economic regulation on private R&D intensity ranging between -0.274 and -0.349. Because we consistently use moderate effects to calculate the contribution of each determinant, we fix the semi-elasticity at the lower level of this range (-0.274). The semi-elasticity belonging to IPR in Bassanini and Ernst (2007) varies between 0.528 and 0.664. Donselaar and Segers (2006) found the effect of intellectual property rights on private R&D expenditures to be more moderate (0.72). This direct output elasticity implies that an increase of 1% on the intellectual property rights index (developed by Ginarte and Park, 1997) leads to an increase of 0.72% in private R&D one year later (in their econometric analysis, the IPR variable was lagged by one year).

Contribution of economic regulation

The data on product market regulation used by Bassanini and Ernst (2007) originate from a study by Nicoletti *et al.* (1999). The data were gathered by the latter authors in 1999, and they were updated by Conway *et al.* (2005). Annex 3 shows how the product market regulation index is constructed. The PMR indicator consists of 16 low-level indicators. Each of the low-level indicators captures a specific aspect of the regulatory regime. In total, the low-level indicators span most of the important aspects of general regulatory practice, in addition to several aspects of industry-specific regulatory policies (Conway *et al.*, 2005). The indicator inward-oriented regulation uses a scale from 0 to 6: a score of 0 indicates a low level of inward-oriented economic regulation, whereas a score of 6 indicates a high level. In 2003, the US had a score of 1.3 on this index, and the EU15 had a score of 2.1.

Annex 1 presents calculations illustrating that, in 2003, the position of the EU15 on inward-oriented economic regulation explained roughly 0.30 percentage points of the total intrinsic R&D shortfall of the EU15 relative to the US. Because inward-oriented economic regulations in the EU explains a significant part of the total R&D shortfall in the EU relative to the US, it would be interesting to identify exactly which aspect of the regulatory regime causes the weak position on this driver of business R&D.

Table 1. Low-level indicators of inward-oriented economic regulation, 2003

	Scope of public enterprise sector	Size of public enterprise sector	Direct control over business enterprise	Use of command & control regulation	Price controls	Legal barriers	Antitrust exemptions
EU15	0.8	0.3	0.6	0.6	0.2	0.2	0.4
US	0.4	0.1	0.2	0.2	0.1	0.1	0.2

Source: Conway *et al.*, 2005.

In Table 1, the position of the EU15 and the US on the low-level indicators of inward-oriented economic regulation are presented for 2003. Annex 3 provides more information on how the indicator *inward-oriented economic regulation* can be broken down into these sub-indices.

The US outperformed the EU15 on each of the low-level indicators. The difference is most prominent on the following indicators: *scope of public enterprise sector*, *direct control over business enterprise* and the *use of command & control regulation*. The definitions of these low-level indicators can be found in Conway *et al.* (2005, p. 9). The indicator *scope of public enterprise* measures the pervasiveness of state ownership across business sectors as the proportion of sectors in which the state has an equity stake in at least one firm. The indicator *direct control over business enterprise* encompasses the existence of government special voting rights in privately-owned firms, constraints on the sale of state-owned equity stakes, and the extent to which legislative bodies control the strategic choices of public enterprises. The indicator *use of command & control regulation* measures the extent to which the government uses coercive (as opposed to incentive-based) regulation in general, as well as in specific service sectors.

Contribution of the IPR regime

Data on IPR regimes were gathered by Ginarte and Park (1997) and updated by Park and Wagh (2002). They constructed an index of intellectual property rights, consisting of the following five underlying factors:

1. Coverage (the range of subjects that can be patented)
2. Duration (length of protection)
3. Enforcement (mechanisms for enforcing patent rights)
4. Membership in international patent treaties (for example the Paris Convention and Revisions)
5. Restrictions on patent rights (for instance compulsory licensing)

Table 2. Index of intellectual property rights, 2000

	Coverage	Duration	Enforcement	Membership	Restriction	Overall
EU15	0.82	1.0	0.93	1.0	0.52	4.28
US	1.0	1.0	1.0	1.0	1.0	5.0

Source: Park and Wagh, 2002.

Countries are assessed on each of these categories (ranging from 0 to 1). A score of 1 indicates that a country maintains the international standard period of protection (i.e. 20 years). Table 2 shows the estimated position of the EU15 and the US on these indicators.¹⁵ The EU falls short primarily on the sub-index *restrictions on patent rights*. This sub-index measures the extent to which patent holders are protected against the risk of forfeiting their patent rights. The index discriminates between three sources of protection loss: 1) ‘working’ requirements, 2) compulsory licensing and 3) revocation of patents.¹⁶

The overall position of the EU15 on the total index of IPR can be calculated for thirteen EU15 countries (including Finland and Portugal) and was extrapolated to cover the year

¹⁵ The EU15 average concerns a weighted average (based on GDP) without the countries Finland, Greece, Luxembourg and Portugal.

¹⁶ See Ginarte and Park (1997, p. 287) for a further explanation of these three sources of protection loss.

2001. Because changes in the IPR regime have an effect on the R&D expenditure of business one year later, we need only the overall position of the EU in 2001 to calculate its contribution to the R&D gap in 2002. In 2001, the overall position on the IPR index in the EU15 was 4.31, whereas the position of the US remained at 5.0. Based on the calculations in Annex 1, we can conclude that the European IPR regime contributes 0.14 percentage points to the European R&D shortfall in 2002.

Conclusion

The position of the EU15 on inward-economic regulation and IPR explains a significant part of the EU15 R&D shortfall compared to the US. We can tentatively conclude that fostering competition and deregulation in combination with a more rigorous IPR system could be an efficient strategy for the EU to narrow its R&D shortfall vis-à-vis the US. However, determining the most effective policy measures to realise a downscale of economic regulation and enhance the IPR system is a subject that needs more specific attention.

3.8 Financial factors

A well-developed financial climate has a significant impact on the level of R&D activities conducted in the business sector. For example, the *profitability* of businesses is important for R&D investment decisions of businesses for two reasons. First, profits of firms are an important internal source of R&D financing (see for instance Himmelberg and Petersen, 1994). Second, the current profitability of a firm is a good indicator of future revenues that can be achieved with new investments, including R&D investments.

In addition, *the real interest rate* and the availability of *bank credits* are important indicators that represent the costs and possibilities of receiving external financing for R&D. The interest rate is likely to be negatively correlated with business R&D for two reasons. First, future revenues from R&D projects must be discounted for the current interest rate. Second, a higher interest rate decreases cash flows, thereby reducing the financial means to invest in R&D. The availability of *bank credits* is presumed to have a positive correlation with private R&D expenditures; as such credits generate funds for financing R&D. This variable is measured as the level of bank credits provided to the private sector, as a percentage of GDP.

The effect of the *business cycle* on the R&D intensity can be divided in two components. The business cycle generates a positive effect on private R&D, because relatively high profitability of businesses in high-growth periods leads to higher R&D investments. However, the business cycle also constitutes a negative effect, because R&D expenditures concern long-term investments. As a consequence, the growth of R&D expenditure is not expected to keep pace with GDP growth during an economic boom. This has a negative effect on the R&D intensity. Because the positive effect of higher profitability on businesses R&D is already captured by the capital income quote (see below), we expect that the second (negative) effect prevails. The business cycle is therefore expected to have a negative relationship with business R&D.

Contribution of financial variables

Much research has been conducted on the influence of firm profitability on private R&D expenditure. Most of this research, however, consists of cross-sectional studies at the micro level (for a review of the existing literature, see Symeonidis, 1996; Hall, 2002). Donselaar and Segers (2006) examine the effect of profitability on private R&D expenditure at the macroeconomic level. Because no international comparable data are available on the profitability of businesses, the authors use the *capital income quote* as an indicator of profitability in their panel data estimates. The capital income quote is defined as the gross capital income as a percentage of business value added. Although the capital income quote thus covers more than profitability, it is still a useful indicator. The elasticity found by Donselaar and Segers (2006) is 0.14. This implies that, when gross capital income as a percentage of value added of firms rises by 1%, private R&D expenditure as a percentage of the GDP rises by 0.14%. Based on the calculations in Annex 1, we are able to derive that the lower capital income share in the EU15 (35.0% in 2002) relative to the US (36.5% in 2002) contributed only marginally (0.01 percentage points) to the R&D gap.

Guellec and Ioannidis (1997) find a semi-elasticity for the effect of the *real interest rate* on the private R&D intensity of -0.03, with a delay of three years. This means that an increase of one percentage point in the long-term real interest rate results in approximately 3% decrease in private R&D expenditure three years later. The calculations in Table A.1 of Annex 1 show that, in 2002, the lower real interest rate in the EU in 1999 (3.0%) relative to the US (4.2%) had a beneficial impact of 0.04 percentage points on the R&D position of the EU relative to the US in 2002.

Lederman and Maloney (2002), Bebczuk (2002) and Donselaar and Segers (2006) have conducted empirical research on the effect of the level of bank credits provided to the private sector (as a percentage of GDP) on the level of business R&D. Because of the arguments mentioned in the methodological explanation (Section 3.1), the elasticity of Donselaar and Segers (0.11) is used to quantify the contribution of the availability of bank credits on the R&D intensity. To the best of our knowledge, Donselaar and Segers (2006) are the only authors to examine the impact of the business cycle (defined here as the actual GDP divided by a five-year progressive average of GDP) on private R&D. They found an elasticity of -0.67. The calculation of the contribution of bank credits and the business cycle, respectively, can be derived from Table A.1 in Annex 1. The higher availability of bank credits in the EU had a positive effect of 0.07 percentage points on the R&D position of the EU relative to the US in 2002. In addition, the business cycle conveyed a marginal positive contribution of 0.01 percentage point in 2002.

3.9 Other factors

The list of determinants dealt with in the previous sections is by no means exhaustive. There are some conceivable determinants that also could have an important impact on the R&D position of countries, for instance the degree of protectionism, cultural aspects and of human capital. There are two reasons why these factors were omitted from our analysis to disentangle the European R&D shortfall compared to the US:

- (i) knowledge from the literature on the impact of certain drivers on private R&D is ambiguous;
- (ii) data on drivers of private R&D in order to compare the European situation with that of the US in 2002 are not available.

To give an example, theoretically the amount of *human capital* in a country should have a major influence on a country's R&D expenditure.¹⁷ After all, human capital is the main input for R&D processes. In the first place there is only few research done on this topic, which makes it hard to quantify the effect of human capital on private R&D. Secondly, the effects that are found, are ambiguous or counterintuitive. For instance, Reinthaler and Wolff (2002) find a significant relationship between human capital and private R&D. However, if country dummies are included in the estimated specification (to control for unobserved heterogeneity), the human capital no longer has a significant impact on private R&D. A similar problem applies to the paper by Becker and Pain (forthcoming). They find a significant positive effect of the number of scientists and technicians in R&D professions on private R&D expenditure. However, this number relates directly to the number of R&D personnel and thus represents a significant part of private R&D expenditure itself. Various other studies find little or no empirical evidence on the importance of human capital on private R&D expenditure (see, for instance, Bebczuk, 2002; Kanwar and Evanson, 2003).

A similar argumentation can be given for other (possibly) relevant factors, like culture. Therefore, we conclude that more research is needed before making any valid statements about the effects on private R&D expenditures of the factors that were omitted in this study.

4. OVERALL DECOMPOSITION

The US has outperformed the EU15 on the amount of private R&D expenditure as a percentage of GDP for a long time. Within the scope of the European policy goals (Lisbon agenda and Barcelona target), this R&D gap should be narrowed significantly. In 2002, the R&D gap between the EU15 and the US was 0.63 percentage points, based on OECD ANBERD data. The objective of this study is to provide more insight into factors that are responsible for the European shortfall in private R&D vis-à-vis the US.

The total shortfall of the EU15 can be divided into two main parts: a *sector composition effect* and an *intrinsic effect*. The sector composition effect between countries represents differences in the relative share of knowledge-intensive industries within the total economy. The contribution of the sector composition to the R&D funding gap between the EU15 and the US in 2002 was only 0.08 percentage point. The intrinsic effect is the complement of the sector composition effect and compares differences in the R&D intensity *within* sectors of the EU15 and the US. This intrinsic effect is responsible for the

¹⁷ Human capital refers to the set of skills that an individual has acquired through education, training and experience, and which increase that individual's value in the marketplace.

remainder (0.54 percentage points) of the private R&D gap. In the decomposition analysis performed for this study, the intrinsic effect is disentangled further into multiple components (see Table 3).

Table 3. Decomposition of R&D gap between EU15 average and the US (EU15-VS), 2002, contributions in percentage points

Determinants	Contribution
Sector composition effect	-0.08%
Intrinsic effect	-0.54%
Foreign R&D investments	-0.11%*
Government funding of private R&D	-0.14%*
Fast-growing firms	-0.03%
Openness of the economy	+0.02%
Public R&D	
Higher education R&D	+0.01%
Public research institutions	-0.05%
Inward-oriented economic regulation	-0.30%**
Intellectual property rights	-0.14%
Capital income share (CIQ)	-0.01%
Real interest rate	+0.04%
Business cycle	+0.01%
Bank credits	+0.07%
Interaction effect	-0.01%
Residual	+0.10%
Total R&D shortfall	-0.63%

Commentary: * 2001, ** 2003.

The most important explanation behind the R&D gap is provided by institutional differences between the EU15 and the US. The higher level of *inward-oriented economic regulation* in the EU15 vis-à-vis the US accounts for roughly 0.30 percentage points of the total gap. This high contribution is caused mainly by differences on three low-level indicators that are part of *inward-oriented economic regulation*: the *scope of the public enterprise sector*, *direct control over business enterprise* and the *use of command & control regulation*. In addition, institutional arrangements concerning intellectual property rights explain a significant part of the R&D gap: differences between the IPR regimes of the US and the EU15 contribute 0.14 percentage points to the total gap. Other important explanations concern *government funding of private R&D* and *foreign R&D investments*, which account for 0.14 and 0.11 percentage points of the R&D gap, respectively.

Adding all of the partial contributions together reveals a total negative intrinsic effect of 0.63 percentage points; the effect is thus overestimated by 0.10 percentage points. There

are numerous explanations for this overestimation. For example, a number of determinants (e.g. culture, human capital and outward R&D) have been omitted, largely because of data availability reasons or lacking empirical evidence. These missing determinants could have contributed positively to the European R&D position compared to the US, thereby counterbalancing the overestimated negative intrinsic effect. As previously noted, we lack the required information on some of these determinants to include them in this paper. Secondly, because of the partial character of this study, omitted variable bias could also explain some of the slight overestimation of the intrinsic effect (see also Section 3.1).

Some remarks should be added on the dataset used for separating the intrinsic effect from the sector composition effect. Although these data are much more comparable between countries than in the past, there are still some measurement problems when comparing R&D intensities of sectors between countries. Especially the allocation of R&D conducted in the services sector causes some serious problems, which is already dealt with in Section 2. Therefore, future efforts into harmonisation of the data are recommended.

Despite these measurement problems, the analyses in the paper indicate that, in contrast to conventional wisdom, the R&D gap between the EU and the US is not caused by a less R&D intensive economic structure of the EU relative to the US; a factor that is largely exogenous in the short term. Instead, a significant part of the gap seems to be policy-sensitive, as institutional factors (e.g. inward-oriented regulation, the IPR regime and government funding of R&D) play a major role in explaining the gap. Here lies a challenge for European policymakers – at both the national and European level – to create more favourable institutional conditions and to foster direct R&D stimulation in order to improve the European R&D performance.

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ANNEX 1. CONTRIBUTION OF VARIABLES WITH A MULTIPLICATIVE SPECIFICATION

Many variables have a multiplicative relationship with business R&D. The calculation of their contribution to R&D gaps is less straightforward than it is for determinants with an additive relationship (Section 3.2 to Section 3.5). In this annex, we show how to conduct these calculations. Depending on the functional form, the estimated effect of a certain determinant must be transformed into a multiplicative specification. This transformation is different for logistic and semi-logistic specifications. Below, we show examples of these both types of specification.

Logarithmic specification

The relationship between the openness of the economy and business R&D has a logistic functional form. In 2002, the openness to foreign trade in the US was 23.6, and the weighted average openness of the EU15 was 24.9. Based on these raw data, we can derive that the higher openness in the EU15 results in a positive effect on the R&D intensity of the EU15 compared to US of 1.0% ($\Rightarrow 100 \times ((24.9/23.6)^{0.24} - 1)$). This percentage can be used to compute a ‘hypothetical R&D intensity’ for the EU in 2002, assuming that the openness of the European economy is equal that of the US. The calculation is as follows: 1.23% (actual R&D intensity of the EU in 2002) $\times 1/(1+1.0/100) = 1.22\%$. The actual R&D intensity of 1.23% in 2002 minus the ‘hypothetical’ intensity of 1.22% reveals a positive contribution of the openness variable on the European R&D position compared to the US of 0.02 percentage points ($\Rightarrow 1.23\%$ minus 1.22%, see also footnote 10).

Semi-logarithmic specification

Inward-oriented economic regulation and private R&D are related semi-logarithmically: one additional point on the index inward-oriented economic regulation (on a scale of 0 to 6) leads to a decrease in private R&D intensity by 0.27 to 0.36 percentage points (Bassanini and Ernst, 2007). By linking the semi-elasticity of 0.27 (we choose the lower level of this range) to the relative position of the EU15 (vis-à-vis the US, 2003) with regard to economic regulation of 0.8 (2.1 minus 1.3), the negative impact of economic regulation in 2003 on European R&D intensity can be fixed at 19.6% ($\Rightarrow 100 \times (e^{(0.8 \times -0.27)} - 1)$). This percentage can be used to compute a ‘hypothetical R&D intensity’ for the EU in 2002, which represents a situation in which the level of inward-oriented economic regulation in the EU is equal to that in the US. The hypothetical R&D intensity is: 1.23% (actual R&D intensity of the EU in 2002) $\times 1/(1+19.6/100) = 1.53\%$. The actual R&D intensity of 1.23% in 2002 minus the ‘hypothetical’ intensity reveals a negative contribution of the European position on inward-oriented economic regulation on the European R&D position compared to the US of 0.30 percentage points ($\Rightarrow 1.23\%$ minus 1.53%).

Table A.1 Contribution of determinants with a multiplicative specification

	Method of calculations	Openness	HERD	GOVERD	Bank credits	Business cycle	Interest rate	Economic regulation	IPR	CIQ	Interaction effects	Sum of partial effects
Year of observation		2002	2002	2002	2002	2002	1999	2003	2001	2002		
Value EU15 average	A	24.9	0.42	0.24	1.05	0.98	3.0	2.1	4.31	35.0		
Value US	B	23.6	0.36	0.32	0.63	0.99	4.2	1.3	5	36.5		
Elasticity (semi-elasticity: *)	C	0.24	0.20*	0.47*	0.11	-0.67	-0.03*	-0.27*	0.72	0.14		
Position of the EU15 relative to the US	$D = A / B$ $D^* = A - B$	1.05	0.06	-0.08	1.68	0.99	-1.2	0.8	0.86	0.96		
Effect by linking position to elasticity	$E = D^c$ $E^* = e^{(D^* \times C)}$	1.01	1.01	0.96	1.06	1.01	1.04	0.80	0.90	0.99	0.78 ¹⁾	
Effect on EU15 R&D intensity due to its position on the determinant relative to the US (in percentages)	$F = 100 \times (E - 1)$ $F^* = 100 \times (E^* - 1)$	1.25	1.21	-3.67	5.88	0.64	3.54	-19.63	-10.11	-0.58	-21.76	
Hypothetical R&D intensity of the EU15, assuming the position on the determinant is equal that of the US	$G = I \times 1 / (1 + F / 100)$ $G^* = I \times 1 / (1 + F^* / 100)$	1.22	1.22	1.28	1.16	1.22	1.19	1.53	1.37	1.24	1.58	
Partial effect (as a percentage of GDP)	$H = I - G$ $H^* = I - G^*$	0.02	0.01	-0.05	0.07	0.01	0.04	-0.30	-0.14	-0.01	-0.34	-0.35²⁾
R&D intensity EU in 2002	I	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	

Commentary: ¹⁾ Equals the product of the 'E'-values of all determinants, thus $(1.01 \times 1.01 \times 0.96 \times 1.06 \times \dots)$. ²⁾ Equals the sum of all partial effects, thus $(0.02 + 0.01 + -0.05 + 0.07 + \dots)$.

Table A.1 presents an overview of the contribution of all included variables in this study that have a multiplicative specification. In column 2 of Table A.1, the method of calculation is generalised by equations. The equations marked by an asterisk (*) correspond to semi-logarithmic relationships.

Interaction effects

When assessing the partial contribution of determinants that use multiplicative expressions, it is important to consider the interaction effects between these determinants. The size of the interaction effects is examined by using a simple multiplicative interaction model, which is presented in Table A.1. The table shows the partial contributions of the determinants that use multiplicative expressions. To test whether significant interaction effects between these determinants occur, we first multiply all multiplicative effects.¹⁸ Using the equations in the second column, this figure (0.78) can be transformed into a cumulative total contribution to the R&D gap of 0.34 percentage points. The size of the interaction effect can be derived by subtracting this cumulative figure from the sum of all separate partial effects. The sum of the partial effects equals 0.35 percentage points. We can conclude that there is a marginal interaction effect of 0.01 percentage points.

¹⁸ These multiplicative effects are determined by linking the relative position of the EU to (semi-) elasticities.

ANNEX 2. CONTRIBUTION OF FAST-GROWING BUSINESSES

In 2002, the private R&D intensity in the EU amounted to 1.23% of GDP. Because EIM data concern only businesses in the size class of 50 to 1,000 employees and our decomposition analysis regards total economy, we need to know the share of total private R&D intensity that is accounted for by firms 50 to 1,000 employees. Although no international data are available concerning this share, Statistics Netherlands calculated this share for the Netherlands at 57%. The OECD also reports data on R&D shares for two size classes (businesses with fewer than 50 employees and firms with 50-249 employees) in the OECD Science, Technology and Industry Scoreboard. Combining these two data sources, we are able to estimate the required shares for the other eight European countries and the US.

As previously stated, firms with 50 to 1,000 employees conduct 57% of total private R&D in the Netherlands. Data from the OECD show that 9.3% of total R&D in the Netherlands is performed by firms with fewer than 50 employees, and 18.3% is executed by firms with 50 to 249 employees. Combining these data shows that 38.7% of R&D is performed by firms with 250 to 1,000 employees, and 33.7% is carried out by firms with more than 1,000 employees. Data (OECD) are also available for the other eight EU countries and the US, for the size classes <50 and 50-249. For all of these countries, the ratio of R&D expenditure by firms with 250 to 1,000 employees relative to the R&D expenditure by firms with more than 1,000 employees is assumed equal to the ratio in the Netherlands ($1.15 = 38.7\%$, divided by 33.7%). Under this assumption, the share of total R&D expenditures for firms with 250 to 1,000 employees can be calculated for each country. The share of total R&D expenditures accounted for by firms with 50 to 249 employees was obtained from the OECD data. This share was added up to the computed share of firms with 250 to 1,000 employees to obtain the share of total R&D expenditures accounted for by firms with 50 to 1,000 employees.

In the EU, 55.7% of R&D is conducted by firms with 50 to 1,000 employees. It is assumed that these shares were the same for both 2002 and 2001. The total R&D expenditure in the EU in 2002 was €104.5 billion; €58.2 billion ($\Rightarrow €104.5 \text{ billion} \times 0.557$) was thus spent by firms with 50 to 1,000 employees. Finally, data on the number of firms with 50 to 1,000 employees are required for both the EU and the US. These data (for 2003), which were kindly made available by Pauline de Jong of the EIM, were taken from Eurostat and US Census Bureau.

The number of firms in the EU (i.e. the nine EU countries for which data are available) with 50 to 1,000 employees was 149,320. Of these firms, 13.9% (20,705) are fast growers; 128,615 are thus non-fast-growing. Because fast-growing businesses invest 40% more in R&D, the total number of businesses must be transformed into R&D 'equivalents': $(20,705 \times 1.4) + (128,615 \times 1) = 157,602$. The average R&D expenditure for each R&D equivalent in the size class of 50-1000 employees amounts to €369,200 ($\Rightarrow €58.2 \text{ billion divided by } 157,602$).

Table A.2 Contribution of fast-growing firms to the R&D gap

	Method	EU versus US
Current situation in the EU:		
R&D intensity in 2002, % of GDP	A	1.23
Share of firms with 50-1,000 employees in total private R&D	B	0.557
Private R&D expenditures of firms with 50-1,000 employees, % of GDP	$C = A \times B$	0.68
GDP in 2002	D	€8,495,423,410,115
R&D expenditures in 2002	$E = A / 100 \times D$	€104,493,707,944
R&D expenditures in 2002 of firms with 50-1,000 employees	$F = B \times E$	€58,186,708,265
R&D expenditures of firms of other size classes	G	€46,306,999,679
Share of fast-growing firms (50-1,000 empl.), EU (2000-2003)	H	0.139
Share of fast-growing firms (50-1,000 empl.), US (2000-2003)	I	0.235
Difference between US and EU	$J = I - H$	0.096
Number of firms with 50-1,000 employees	K	149,320
Number of fast-growing firms (50-1,000 employees)	$L = K \times H$	20,705
Number of non-fast-growing firms (50-1,000 employees)	$M = K - L$	128,615
Fast-growing firms spend 40% more on R&D	N	1.4
Number of firms (50-1,000) expressed in 'R&D-equivalents'	$O = L \times N + M$	€157,602
R&D expenditures (50-1,000) per 'R&D-equivalent'	$P = F / O$	€369,200
Situation if share of fast-growing firms in the EU is equal to the US:		
Number of fast-growing firms (50-1,000 employees)	$Q = K \times I$	35,090
Number of non-fast-growing firms (50-1,000 employees)	$R = K - Q$	114,230
Private R&D of fast-growing firms (50-1,000 employees)	$S = Q \times P \times N$	€18,137,431,441
Private R&D of non-fast-growing firms (50-1,000 employees)	$T = R \times P$	€42,173,662,773
Private R&D of firms with 50-1,000 employees	$U = S + T$	€60,311,094,214
Total private R&D expenditures	$V = U + G$	€106,618,093,894
Total private R&D expenditures, % of GDP	$W = V / D \times 100$	1.26
Difference between hypothetical and current situation	$X = W - A$	0.03

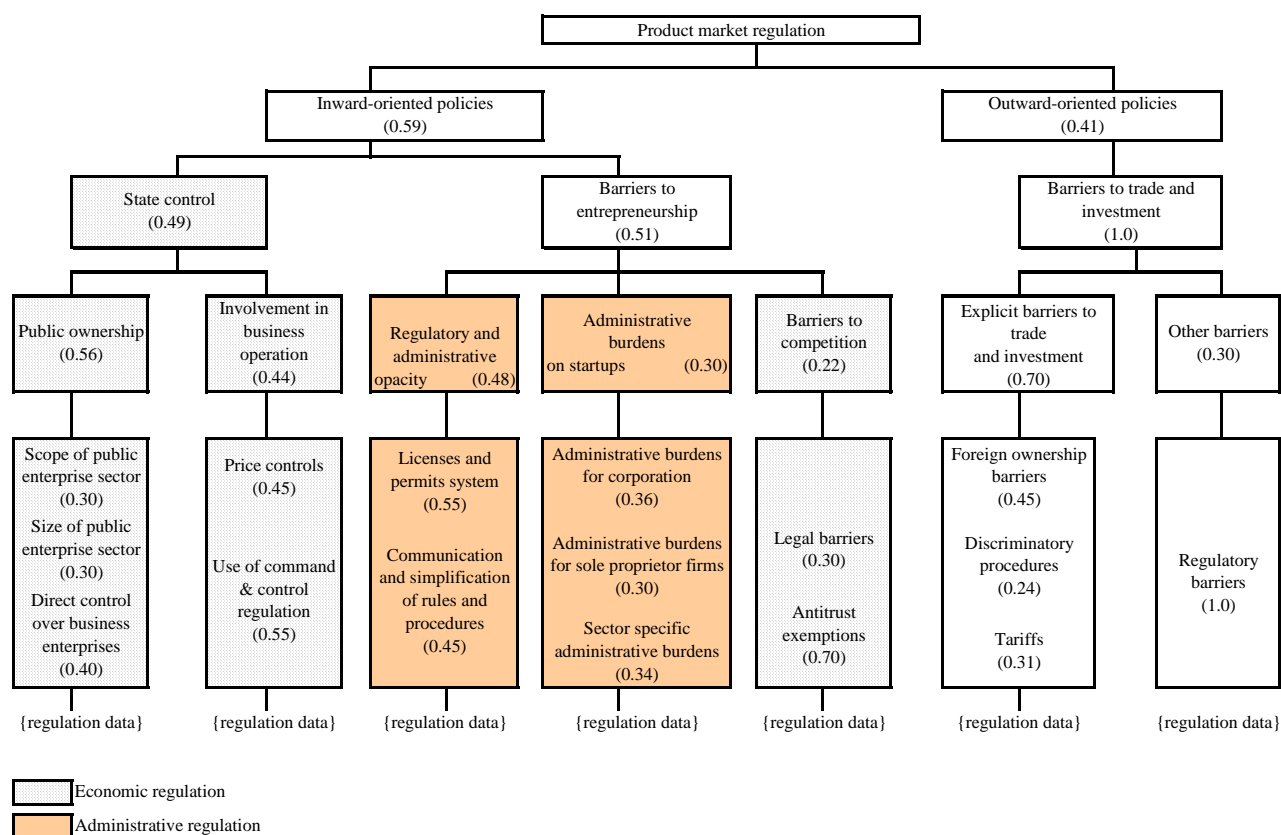
Source: Eurostat; U.S. Bureau of the Census; OECD, Main Science and Technology Indicators, 2006-2.

We hypothesize that the share of fast-growing firms in the EU is equal to that share in the US, implying an increase from 13.9% to 23.5%. In that situation, the number of fast-growing firms in the EU would be 35,090 ($149,320 \times 0.235$) instead of 20,705. The number of non-fast-growing-firms would decline to 114,230. The total R&D expenditure of all firms with 50 to 1,000 employees would be €60.3 billion ($\Rightarrow (35,090 \times 1.4) \times$

$369,200 + 114,230 \times 369,200$). The R&D expenditures of the firms in other size classes (i.e. fewer than 50 employees and more than 1,000 employees) would be €46.3 billion ($\Rightarrow (1 - 0.557) \times \text{€}104.5 \text{ billion}$). In summary, the total R&D expenditures in the EU would be €106.6 billion instead of €104.5 billion. This means that the R&D intensity of the EU would be 1.26% instead of 1.23%. In Table A.2, all calculations are put together (with the corresponding equations in the second column).

These results show that the R&D intensity of the EU would be 0.03 (1.26% minus 1.23%) percentage points higher if the share of fast-growing companies in the EU were equal to that of the US.

ANNEX 3. THE PMR INDEX SYSTEM



Note: Weights were derived from a principal components analysis performed separately on regulatory data entering each of the main domains of regulation (state control, barriers to entrepreneurship, barriers to trade and investment, economic regulation and administrative regulation). A similar principal components analysis was also performed on the domains entering the indicator of inward-oriented policies (state control and barriers to entrepreneurship), and the summary indicator of regulation (inward- and outward-oriented regulations). The principal components analysis was based on the original 1998 data.

Source: Conway *et al.* (2005).