Essays on Merger Policies and on R&D in Europe

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[1] This chapter is joint work with Prof. Dr. Andreas Haufler from the University of Munich.

[57] This chapter is joint work with Christian Helmers (University of Oxford) and Hubert Strauss (EIB Luxembourg).

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Preface

In this dissertation I deal with two different topics that are both relevant for economic well-being. On the one hand I analyse merger policies when merger control is not the only policy instrument at the disposal of welfare maximizing governments. On the other hand I give a foundation of the importance of Research and Development (R&D) by exploiting an enlarged data set of R&D expenditure and capital as well as by treating R&D as an investment in a growth accounting framework. Although both subjects are related by the common motivation to be relevant for welfare maximizing economic policy makers, they differ methodologically as well as with regards to content. While the first part of my dissertation analyzes the use of policy instruments from a purely theoretical perspective, an empirical investigation of R&D in Europe is offered in the second part. Therefore the contribution at hand should be seen as consisting of two parts whereby each part is divided into two chapters. I will give a brief introduction to each of them in the following.

Both chapters of the first part deal with merger control that is interacted with another policy instrument: the optimal setting of taxes. The general idea is that there are many situations where governments have more than a single instrument at their disposal such that it is reasonable to think about potential repercussions between them. This will be investigated in an open-economy setting with non-cooperative governments and profit maximizing firms.

In the literature, merger control is typically considered as an isolated policy problem. Only few papers interact merger control with further policy instruments whereby they usually focus on international trade policies (e.g. Horn and Levinsohn, 2001).

Therefore the first part of the dissertation offers a contribution that combines two strands of the literature, namely the one on strategic merger policies (for an overview see for example Huck and Konrad 2004) with the one of optimal taxation. With respect to the latter, I am dealing with optimal commodity taxation in concentrated industries (see e.g. Keen and Lahiri, 1998). The resulting policy analysis can give more realistic insights into policy decisions dealing for example with merger proposals in network industries where specific regulation and sector-specific taxation tools often exist. Nevertheless, priority has been given to an identification of the underlying incentives for governments and firms in a merger scenario by choosing a very simple model instead of trying to rebuild reality. The next paragraphs introduce the basic set-ups as well as some main findings of these two chapters belonging to the first part.

Chapter 1, merger policy and tax competition: the role of foreign ownership

This as well as the second chapter considers an open-economy setting of a concentrated industry that is modelled by standard Cournot quantity competition. There are two countries with national governments having a sector-specific tax or equivalent regulation policy at their disposal to influence the market outcome after a national or an international merger has taken place. Governments anticipate the behaviour of profit maximizing firms. Firms, in turn anticipate governments tax response when they decide on an (inter-)national merger. Finally, I study the implications for national welfare maximizing merger policy when countries non-cooperatively set their production-based tax rates. Moreover, a special focus lies on the consideration of different ownership structures with respect to the location of the firms' shareholders. I find that when foreign firm ownership is low in the pre-merger situation, non-cooperative tax policies are more efficient after a national than an international merger and smaller synergy effects are needed for this type of merger to be proposed and cleared. In contrast, cross-border mergers dominate when the degree of foreign firm ownership is high initially.

These results give a complementary explanation to many others, why we observe an increasing international portfolio diversification together with a rising share of cross-border mergers in many countries.

Chapter 2, merger policy and tax competition: the role of trade costs

This chapter continues the analysis of Cournot competition in oligopolistic markets where governments choose an optimal production tax according to the market structure. In fact, I use the same basic setting but with further elements and a completely different focus: trade costs, which were not included in the previous model, are added such that their influence on optimal tax policy and merger control decisions can be analysed. Such savings, which can also be originated in the avoidance of trade barriers, are still important and unlikely to vanish completely. This can for example be seen by the ongoing negotiations to overcome further trade barriers in the Doha Development Agenda of the WTO. The chapter finally focuses on a cross-border merger that allows the merging firms to save on such trade costs. It is shown in a symmetric setting with linear demand that the cross-border merger is not profitable for the merging firms despite the implied savings. This is due to a positive tax response of the national welfare maximizing governments and implies that Salant's famous merger paradox (Salant et al. 1983) still holds here. Nevertheless, a cross-border merger is potentially welfare improving due to the avoidance of inefficient trade. Overall, additional synergy effects are needed in order to turn the cross-border merger profitable and welfare enhancing at the same time.

In the second part of my dissertation, the perspective changes from a theoretical analysis of merger control and tax competition to an analysis of empirical findings on the importance of R&D in Europe. In the first chapter of this part, an overview over business R&D expenditures and capital in Europe is given by putting R&D into various instructive relationships. This analysis is based on new estimates for 22 countries that are constructed by updating and enlarging a database of the EU KLEMS consortium (see EU KLEMS, 2008a). In the second chapter of this part, some of these new estimates are used in order to show the implications of treating R&D capital as investment in a classical growth accounting framework following Solow (1957). The overall purpose of this final chapter is to demonstrate the importance of an adequate treatment of R&D as investment by discussing this framework and by using some illustrative examples.

Hence, there are again two related chapters to which I will give a first overview in the following. Taken together, I contribute to the traditional literature of R&D that has identified R&D as an important factor for fostering productivity (beginning with Arrow, 1962) as well as to the present discussion about an adequate treatment of such intangibles in growth accounting (e.g. Corrado et al. 2005) and in national accounts in general, see for example the new recommendations in the system of national accounts 2008(European Commission et al., 2009).

Chapter 3, business R&D expenditure and capital in Europe

This chapter provides insights into the distribution and relation of R&D expenditure and capital in 20 European countries at the industry level as well as on the aggregate whereby the US and Japan are added for additional comparisons. The analysis focuses especially on R&D capital stocks where new estimates of business R&D capital stocks are presented.

A first core result is that with 9 percent of GDP, the aggregate EU business R&D capital stock falls short of its US and Japanese counterparts. Moreover, also large disparities within the EU are detected: R&D capital stocks are much lower in the southern and the new member states, reflecting large and persistent disparities in R&D expenditure. Investigating the evolution of R&D capital stocks, there was also hardly any convergence over the past decade within the EU.

Turning to the industry-level, our data show that the R&D capital stock is concentrated on three broad technology-intensive manufacturing industries: chemicals and pharmaceuticals, transport equipment and finally also on the industry category computing, communication and other equipment. These industries are analysed in more depth throughout the chapter. Another perspective, taken at the end of the analysis, is to see how R&D capital is distributed in relation to tangible capital across industries as well as across countries. Thereby, the resulting ratios suggest marked differences in how R&D and tangible capital are combined in production.

Finally, this chapter also provides a first insight into the implication of R&D capital stocks for growth accounting: a positive correlation between R&D capital stocks and subsequent growth in total factor productivity as the residual of a standard growth accounting framework can be seen in our data set.

Chapter 4, R&D as an investment in growth accounting – with an application to Germany and Slovenia

Corrado et al.(2005, p.19) already state that "any outlay that is intended to increase future rather than current consumption should be treated as capital investment". From this perspective, there is no justification why R&D should be treated differently than investment in physical capital. If done so, this has consequences for national accounts: the level of gross value added (GVA) rises which is clarified in the beginning of the analysis in this chapter. It investigates the inclusion of R&D capital stocks in a growth accounting framework from a methodological perspective and gives a first snapshot on the implications for the sources of growth in some industries of Germany and Slovenia.

Recognizing the rise of GVA, the chapter focuses on the implications of an identical treatment of R&D and physical capital for a classical growth accounting model. Special emphasis lies on the discussion of crucial assumptions, especially because R&D is partly non-rival.

The presented framework is finally applied to some R&D intensive industries in Slovenia and Germany using the R&D capital stock data outlined in the third chapter. Due to some data limitations with respect to the complementary EU KLEMS database (see EU KLEMS, 2008a and 2009), only a snapshot on the results of a different treatment of R&D can be given so far. Nevertheless, this gives some first interesting insights because capital stock data for Slovenia were not existent before: especially the rise in the level of industry GVA also translates into higher growth rates of GVA in the shown example (Chemical Industry). Finally, total factor productivity shrinks if R&D is included as additional capital asset. Moreover, the chapter gives an outlook how this newly calculated total factor productivity – that is not identical to the one used in the previous chapter - could be used in future research.

Finally note that all these chapters are written as individual contributions such that they can be read independently. Therefore some repetition, especially in chapters two and four, has been inevitable.

Part I

Merger Policy and Tax Competition

- a theoretical analysis -

Chapter 1

Merger policy and tax competition: the role of foreign ownership[1]

1.1 Introduction

Mergers have played a prominent role over the past decades, and international merger activity has grown particularly fast. During the period 1980-2000 the annual number of mergers and acquisitions ($M\&A$) has increased more than fivefold in a large, worldwide sample of firms and the growth of cross-border mergers was even higher, reaching more than one quarter of the total by the end of this period (Gugler, 2003, Figure 1 and Table 2A; Hijzen at al., 2008, Table 1). The number of cross-border mergers peaked in 2000 and, after a drop in the first years of the new century, rose again to an annual level of almost 7.000 cross-border mergers in the year 2006 (UNCTAD, 2007). One factor contributing to this rise in merger activity has been the changing policy stance of merger control authorities. In many countries these have moved away from a strict evaluation of market concentration ratios towards a flexible case-by-case approach, where the increased concentration of industry is weighed against possible efficiency gains and other positive side effects of the merger.[2] In fact, the most recent guidelines on the assessment of horizontal mergers in the European Union (2004) stipulate that efficiency gains or improved products and services associated with mergers should be

[1] This chapter is joint work with Prof. Dr. Andreas Haufler from the University of Munich.

[2] See e.g. Mueller (1997) for a review of the history of merger policy in the United States.

taken into consideration, and the overall benefit to consumers should be the overriding objective in assessing the desirability of a proposed merger.

This increased flexibility of merger control and the emphasis placed on broadly defined welfare objectives raises the issue of whether merger policy should also be evaluated in the light of its interaction with other policies, in particular in the field of taxation. Indeed there are indications that such interactions are already playing a role in merger decisions. A case in point are network sectors, such as telecommunications, electricity, or gas where merger activity has been strong in recent years due to expanding profit opportunities in recently liberalized markets. In many cases cross-border mergers were cleared by regulation authorities, even though they occurred in markets that were until recently regarded as 'sensitive' areas of national economies.[3] At the same time, network industries are characterized by increasingly stringent regulation and, in many cases, additional taxation.

In the German electricity market, for example, a series of mergers between the eight large electricity providers occurred between 1997 and 2002. This left only four large players in the market, two of which have sizable shares of foreign ownership.[4] Nevertheless, all these mergers were cleared by the German regulation authorities. At the same time Germany introduced a new electricity tax in 1998, and the initial rate of this tax increased by more than 50% until 2003. Moreover, following the European Union's directives, Germany extended sector-specific price regulation to the electricity sector in 2005 introducing, for the first time, price caps for the access charges of the large, network-owning companies. A similar pattern was observable in the German natural gas market, where industry consolidation also concurred with stricter regulation and increased specific taxation since the late 1990s.

Another example is the United Kingdom, which has fully liberalized its energy and utility markets in the early 1990s. In this process, foreign companies - among them *E.ON* and *RWE* - took over sizable parts of the British network industries. In 1997

[3] There are, of course, exceptions. One is the highly publicized case of the leading Spanish electricity provider *Endesa*, whose takeover by the German-based *E.ON* company was vigorously opposed by the Spanish merger control authorities. This led to *E.ON* finally withdrawing its bid in 2007.

[4] The four large remaining companies are *E.ON*, *RWE*, *EnBW* and *Vattenfall*. Of these, *Vattenfall* is a 100% subsidiary of the Swedish-owned parent company and 34.5% of the shares of *EnBW* are held by the French-owned *EDF*.

the U.K. government levied a one-time 'windfall profit tax' on all privatized utilities including water, electricity, gas, and telecommunications. Since then a renewed imposition of this tax has been repeatedly discussed as a complement to the regulation of prices through the regulation authority Ofgem (Office of Gas and Electricity Markets).[5]

Finally, there are also examples where merger policies interact with industry- and firm-specific subsidies, which are granted in order to improve or maintain the competitiveness of domestic products in world markets. A case in point is the French electricity and transport company *Alstom*, which received financial aid from the French government that was approved by the European Commission in 2004. In exchange the European Commission mandated that *Alstom* be opened to industrial partnerships. A possible takeover by the German firm *Siemens* was blocked by the French government, however. Arguably, this negative reaction to the potential merger was caused at least in part by the French government anticipating that its financial aid might eventually benefit a foreign-owned company.

Against the background of these and other examples, we argue in the present paper that the possibility to levy industry-specific taxes and subsidies in a nationally optimal way can have important repercussions on the position that national regulation authorities take vis-à-vis a national or an international merger. In particular, we argue that merger authorities will be more likely to accept a merger proposal, if they can safeguard the interests of their resident population by means of tax and regulation policies, once the merger has been enacted. To analyze the interaction between tax and merger policies we investigate a setting of Cournot quantity competition between four producing firms where two firms are located in each of two symmetric countries. Both firms and merger regulation authorities anticipate that countries will adjust their tax policies in a nationally optimal way after a merger has taken place. Hence we model a three-stage game where the merger decision is made in the first stage, tax policies are set in the second stage, and firms choose outputs in the third stage.

An important feature of our model is that each firm may be partly owned by foreigners, where the foreign ownership share is taken to be exogenous in our analysis.

[5] Most recently, this proposal was made in August 2008. See "Fuel firms face threat of windfall profit tax", The Times, 1 August 2008.

This gives an incentive to each government to employ profit taxes that can be partly exported to foreigners. This *tax exporting effect* is familiar from the theoretical tax competition literature (see e.g. Huizinga and Nielsen, 1997; Fuest 2005). Its empirical importance has recently been demonstrated by Huizinga and Nicodème (2006), who show for a European sample that countries with a high share of foreign firm ownership also impose relatively high corporate taxes.

Our analysis considers both a (single) national merger between two firms in the same country, and a (single) international merger between a home and a foreign firm. For each type of merger we analyze under which conditions the merger will be simultaneously proposed by the merging parties, and accepted by the merger regulation authority. The latter is assumed to base its decision on the merger proposal on the comparison of the representative citizen's welfare in the absence and in the presence of the merger. We assume that each merger is associated with exogenous savings in unit production costs. We then ask whether a national or an international merger is more likely to occur, in the sense of requiring a lower critical level of cost savings for its adoption.

Our analysis shows that the answer to this question depends critically on the degree of foreign firm ownership. When all firms are nationally owned prior to the merger, then a national merger will lead to more efficient tax policies, as compared to the international merger, and the national merger will be proposed and cleared for a lower critical level of cost savings. This result is reversed, however, when the level of foreign firm ownership is high initially. These results of our analysis point to a link between the global trend towards a more geographically dispersed ownership structure of firms, and the recent surge in cross-border merger activity.

Our analysis relates to two strands in the existing literature. First, there is a growing recent literature on merger policies in open economies.[6] This literature, however, typically regards merger control as an isolated policy problem for national or international regulators. The literature that analyses the interaction of merger control with

[6] Contributions to this literature that relate to our analysis include Barros and Cabral (1994), Head and Ries (1997), Horn and Persson (2001), Bjorvatn (2004), Lommerud et al. (2006), Haufler and Nielsen (2008) and Südekum (2008).

other policy instruments is scarce, and it almost exclusively focuses on international trade policies as the additional policy variable (Richardson, 1999; Horn and Levinsohn, 2001; Huck and Konrad, 2004; Saggi and Yildiz, 2006). In contrast, the interaction between merger policy and national tax policies has not been addressed in this literature so far.[7] A second literature strand on which our paper builds is the analysis of optimal commodity taxation in oligopolistic markets (see Keen and Lahiri, 1998; Keen et al., 2002; Haufler et al., 2005; Hashimzade et al., 2005). This literature, however, does not address the implications for tax policy that follow from changes in the underlying market conditions as a result of mergers.

The plan of this chapter is as follows. Section 1.2 describes the basic framework for our analysis. Section 1.3 presents the benchmark case of double duopoly, where two firms are located in each country and all four firms compete in both markets. Section 1.4 analyzes the changes in tax policies and welfare when a national merger that generates cost savings is proposed in one of the countries. Section 1.5 carries out the same analysis for an international merger. Section 1.6 asks under which conditions one or the other type of merger is more likely to be proposed and enacted. Section 1.7 concludes.

1.2 The general framework

We consider a concentrated industry in an open economy model of two symmetric countries $i \in \{A, B\}$. In each country i, there are initially two producing firms, indexed with j. Firms 1 and 2 are located in A and firms 3 and 4 are located in B. All firms are engaged in Cournot quantity competition and produce a homogenous good. The location of all firms is fixed throughout our analysis.[8] Each firm can serve the other market by exporting and, for simplicity, there are no trade costs when goods are sold abroad. Hence there are four firms competing in each market in the initial equilibrium.

[7] A recent theoretical paper analyzing the interaction of tax policies and mergers is Becker and Fuest (2010). The focus of their paper is very different from ours, however, and lies on the implications of $M\&A$ activity for the desirability of different international tax regimes.

[8] See Janeba (1998) for an analysis of tax competition (but not of of merger policy) when the firms in the imperfectly competitive industry are internationally mobile.

The sales of firm j in country i are given by x_j^i and the global sales of firm j are denoted x_j. Each firm maximizes its profit independently for each national market. We thus assume that markets are segmented.[9]

Production is modeled in the simplest possible way. Capital (k) is the only factor of production. In the benchmark case without efficiency gains from mergers, each firm requires one unit of capital to produce one unit of output. Hence $x_j = k_j$. Capital is traded internationally at an exogenously given world interest rate r. The cost of capital consists of the interest rate and a unit tax on capital t^i, which is levied in the source country of the investment. Given the above production function, this tax can equivalently be interpreted as an origin-based production tax.[10] In the absence of mergers, the resulting production costs are then $c_1 = c_2 = r + t^A$ for the firms producing in country A and $c_3 = c_4 = r + t^B$ for those in country B.

On the demand side we assume that there is one representative consumer in each market who consumes good x and a numeraire good z, which is produced under conditions of perfect competition. The consumer's utility function is of the quasi-linear form

$$W^i(x^i, z^i) = u(x^i) + z^i, \qquad x^i = \sum_{j=1}^{4} x_j^i \quad \forall\, i \in \{A, B\}, \tag{1.1}$$

where x^i is total consumption of good x in market i. We assume that the representative consumers in the two countries are the owners of all firms and thus the claimants of the residual profit income. Denoting the price of good x in country i by p^i, the budget constraint of the consumer in i is

$$p^i x^i + z^i = \Pi^i + T^i \quad \forall \quad i \in \{A, B\}, \tag{1.2}$$

[9] This assumption simplifies the calculations as firms treat the price in each market as an independent variable. While price discrimination by firms is permitted, it will not occur in equilibrium as markets are symmetric and trade costs are absent (see Brander, 1995, p. 1426).

[10] When the taxes in our model are interpreted as commodity taxes (excise taxes), these have the character of production-based levies when they are imposed in the country of origin and cannot be rebated upon export. This is true, for example, for many energy-related levies. When the tax t is instead interpreted as a factor tax, our specification adopts the view - commonly held in the literature - that capital income taxation follows the source principle. For an analysis that also incorporates residence-based capital and dividend taxes in a setting with mergers, see Becker and Fuest (2009).

where Π^i and T^i are aggregate profit income and tax revenue in country i, respectively.[11] The profits of each firm j are given by

$$\pi_j = \begin{cases} p^A x_j^A + p^B x_j^B - (x_j^A + x_j^B)(r + t^A) & \forall\, j \in \{1,2\} \\ p^A x_j^A + p^B x_j^B - (x_j^A + x_j^B)(r + t^B) & \forall\, j \in \{3,4\}\,. \end{cases} \tag{1.3}$$

An important feature of our model is that the firms producing in country i may not be fully owned by the local consumers. Specifically, we denote by α the (exogenous) share of each firm that is initially owned domestically, whereas $(1-\alpha)$ is the share owned by the representative foreign consumer. We restrict α to be in the range $0.5 \leq \alpha \leq 1$, thus ensuring that foreign owners do not hold a majority in any firm.[12] To simplify notation, we also assume that the domestic ownership share is the same for all firms, i.e. residents of country A hold the share α in firms 1 and 2, whereas residents of country B hold the same share α in firms 3 and 4.

Next, we characterize the behavior of national governments. Governments simultaneously and non-cooperatively choose the tax rate t^i to maximize the utility of their representative citizen. Tax policy in each country thus follows the national interest only and international tax coordination is ruled out. If positive tax rates are chosen, the resulting revenue T^i is redistributed lump-sum to the representative consumer. Conversely, if subsidies are paid to firms, then the costs of these subsidies are met by a lump-sum tax on the domestic resident. Therefore the income of the representative consumer in each country consists of the profit income derived from all firms and the government balance. With quasi-linear utility, we can use the budget constraint (1.2) to substitute out for z^i in the utility function (1.1). National welfare in each country thus equals the sum of consumer surplus, $CS^i = u(x^i) - p^i x^i$, and the consumer's

[11] We thus assume that all capital used in production is owned by residents from third, outside countries. This is for notational simplicity only and implies no loss of generality. With positive capital endowments, an additional fixed source of income would be added to household income in A and B, but this would affect none of our results.

[12] There is substantial empirical evidence for such a 'home bias' in the composition of shareholders' portfolios. See Pinkowitz et al. (2003) for a survey.

income. Hence the governments of countries A and B solve:

$$\begin{aligned}\max_{t^A} W^A &= CS^A + \alpha\sum_{j=1}^{2}\pi_j + (1-\alpha)\sum_{j=3}^{4}\pi_j + t^A\sum_{j=1}^{2}x_j \ , \\ \max_{t^B} W^B &= CS^B + \alpha\sum_{j=3}^{4}\pi_j + (1-\alpha)\sum_{j=1}^{2}\pi_j + t^B\sum_{j=3}^{4}x_j \ .\end{aligned} \tag{1.4}$$

Prior to choosing their tax policy, governments decide on an exogenous national or cross-border merger proposal.[13] In case of a merger we take into account that mergers create exogenous cost savings, which may differ for a national and an international merger. We assume that these cost savings are known to both the merging firms and the government. Hence governments base both their tax policy choices and the decision on whether to permit a merger or not on the true, post-merger costs of production.

This sequence of events is motivated by the fact that the setting of sector-specific taxes or subsidies is typically of a more short-term nature than the (usually irrevocable) decision on a firm merger. Thus when deciding on a merger proposal governments take into account the possibility to tax the profits in the more concentrated market. As we will see below, this is particularly important when firms are partly owned by foreigners. The timing of the game can thus be summarized as follows. In the first stage, a national or an international merger is proposed by the merging firms and governments either reject or clear the proposal, depending on which policy maximizes their national welfare.[14] In the second stage, both governments non-cooperatively set their tax policies. In the third stage, all firms simultaneously choose their profit maximizing output levels.

In the following we first analyze the output decisions by firms and the tax choices of governments in the pre-merger case of double duopoly. The resulting allocation and welfare under this market structure constitutes the benchmark against which the outcome in alternative post-merger scenarios must be judged. We then proceed to study outputs, tax levels, and welfare under a potential national or international merger,

[13] We use the terms 'international merger' and 'cross-border merger' interchangeably.

[14] We assume that a national merger is decided upon by the country which hosts the merging firms, whereas an international merger is cleared by a common regulation authority of the two countries. These assumptions are not restrictive, however. It will be seen that a national merger in country A is never vetoed by country B so that it is sufficient to concentrate on A's decision. For an international merger the equilibrium is symmetric and hence the interests of the two governments coincide.

where only a single merger is permitted to occur in each analysis. Effectively we thus assume that one of the firms in, say, country A is searching for a partner, which could either be the national rival or one of the two firms operating in country B.[15]

1.3 Benchmark: Double duopoly

In this section we derive the optimal tax policies and the equilibrium allocation for the benchmark case of double duopoly. Before we solve the model in closed form by imposing additional restrictions on demand, it is useful to derive the optimal tax policy in the more general framework outlined in section 2. This allows us to identify the different effects that shape tax policy in the second stage of our model. Substituting (1.3) in (1.4), differentiating with respect to t^i and employing the symmetry properties yields for the example of country A (see the appendix for the derivation):

$$t^A = \underbrace{\frac{p' x^i_j}{\sum_{i=A}^{B} \sum_{j=1}^{2} (dx^i_j / dt^A)}}_{(+)} \left[\underbrace{\sum_{j=1}^{4} \frac{dx^A_j}{dt^A}}_{(I)\ (-)} + \underbrace{(2\alpha - 1) \left(\sum_{j=1}^{2} \frac{dx^B_j}{dt^A} - \sum_{j=3}^{4} \frac{dx^B_j}{dt^A} \right)}_{(II)\ (-,0)} + \underbrace{\frac{4(1-\alpha)}{(-p')}}_{(III)\ (+,0)} \right]. \tag{1.5}$$

Here $p' < 0$ is the slope of the inverse demand curve, x^i_j is the supply of firm j to market i (which is the same for all firms and in both markets) and $dx^i_1/dt^A = dx^i_2/dt^A < 0$ and $dx^i_3/dt^A = dx^i_4/dt^A > 0$ are the equilibrium changes of output for market i produced by a representative firm located in country A and country B, respectively. To sign the effects in (1.5), note that a rise in t^A reduces equilibrium output of country A's firms and increases that of B's firms. Moreover, the effect of the tax increase are likely to be stronger in absolute terms for the firms in country A. Hence, for most specifications we would expect that $|dx^i_1/dt^A| = |dx^i_2/dt^A| > |dx^i_3/dt^A| = |dx^i_4/dt^A|$.

It is then straightforward to infer that the first effect (I) in equation (1.5) gives the aggregate change in output supplied to country A's consumers. This effect, which we label the *efficiency effect*, is negative, as an increase in t^A reduces output of country A's

[15] Studying simultaneous merger decisions is beyond the scope of the present analysis. See e.g. Haufler and Nielsen (2008) for a partial analysis of both non-cooperative and cooperative merger games in a setting without endogenous tax policy choices.

firms by more than it increases the output of B's firms. Since the consumption of good x in country A is inefficiently low, this effect calls for subsidizing domestic production. The second effect (II) is a *market share effect*. An increase in t^A reduces the output of country A's firms and raises the output of B's firms, thus redistributing profit income towards the latter. This gives a strategic incentive to each country to subsidize domestic firms (cf. Brander, 1995). The effect is strongest with full national ownership ($\alpha = 1$), and it is absent if the ownership structure of firms is fully diversified internationally ($\alpha = 0.5$). Finally, the third effect (III) is a positive *tax exporting effect*. It describes the incentive to levy a positive tax on output whenever foreigners hold some share in domestic firms ($\alpha < 1$), as part of the tax burden will be shifted to them (cf. Huizinga and Nielsen, 1997; Fuest, 2005). Overall, the sign of nationally optimal tax rates is thus ambiguous in our analysis.

Having discussed the general effects that shape tax policy in our model we now introduce the assumption that utility is quadratic and hence $U^i = ax^i - (x^i)^2/2 + z^i$. This utility function gives rise to linear inverse demands in each market:[16]

$$p^i = a - x^i \quad \forall\, i. \tag{1.6}$$

Solving the game by backward induction, we start with the solution of the firms' optimization problems. Maximizing profits in (1.3) with respect to x^i_j, using the inverse demand function (1.6) and employing the symmetry of the model yields

$$\begin{aligned} x^i_1 = x^i_2 &= \left(a - r - 3t^A + 2t^B\right)/5 \quad \forall\, i \in \{A, B\}, \\ x^i_3 = x^i_4 &= \left(a - r - 3t^B + 2t^A\right)/5 \quad \forall\, i \in \{A, B\}. \end{aligned} \tag{1.7}$$

This shows that output levels of each firm depend negatively on the production-based tax rate in the firm's home country, but positively on the tax rate of the foreign country (which hosts some of its rivals). Moreover, eq. (1.7) shows that $|dx_1/dt^A| > |dx_3/dt^A|$,

[16] This ensures that we can derive closed-form solutions for optimal tax rates and welfare in the different cases. The latter is critical as we want to discretely compare the welfare levels in the double duopoly benchmark and in each of the two merger scenarios.

as postulated above. Substituting (1.7) into (1.3) gives maximized profits

$$\pi_1 = \pi_2 = \frac{2(a - r - 3t^A + 2t^B)^2}{25}; \quad \pi_3 = \pi_4 = \frac{2(a - r - 3t^B + 2t^A)^2}{25} \,. \tag{1.8}$$

In the appendix we derive equilibrium tax rates as a function of the foreign ownership share α, solving the welfare maximization problem (1.4) in the second stage of the game. To minimize the algebra in the main text, our analysis focuses on the polar cases of *full national ownership* ($\alpha = 1$), and *full international ownership diversification* ($\alpha = 0.5$). Since all expressions are monotonous in α in the relevant range, these polar cases determine the bounds for endogenous tax rates and the implied welfare levels in the – more realistic – intermediate cases where $0.5 < \alpha < 1$.

1.3.1 National ownership of firms

With $\alpha = 1$, the Nash equilibrium taxes [see (A.1) in the appendix] are

$$t^i_{(DD)}\big|_{\alpha=1} = \frac{-(a - r)}{4} \quad \forall\, i \in \{A, B\}. \tag{1.9}$$

Hence, governments offer a production or capital subsidy to firms in order to raise output towards its efficient level. In fact, in the special case of full national ownership of firms, the efficient output level is reached and the resulting allocation represents a global Pareto optimum (subscript PO). From (A.3) in the appendix, national welfare in the two countries is

$$W^i_{(DD)}\big|_{\alpha=1} = \frac{1}{2}\,(a - r)^2 = W^i_{PO} \quad \forall\, i \in \{A, B\}. \tag{1.10}$$

The result that non-cooperative tax policy yields an efficient outcome when firms are fully owned by the domestic resident is not obvious in our open economy setting. It is, however, easily explained from (1.5). National governments do not fully internalize the benefits to consumers induced by a production subsidy because, with costless international trade, some part of domestic production will be consumed by foreigners. Therefore the *efficiency effect* (I) is reduced, relative to the case of a closed economy.

However, this incomplete incentive is offset by the strategic *market share effect* (II). In the special case of symmetric countries and zero trade costs, the market share effect exactly compensates for the reduced efficiency incentive. Finally, for $\alpha = 1$ the *tax exporting effect* (III) is absent. Hence in this case each country sets its non-cooperative tax rate at the globally efficient level.[17]

1.3.2 Internationally diversified ownership structure

With foreign firm ownership, two changes occur in equation (1.5). First, the incentive to subsidize domestic firms through the *market share effect* (II) is reduced. Furthermore, each country now has an incentive to tax the profits of its domestic firms through the *tax exporting effect* (III), as profits now partly accrue to foreigners. From (A.1) in the appendix, this leads to positive tax rates when the ownership structure of firms is fully diversified

$$t^i_{(DD)}\big|_{\alpha=0.5} = \frac{2(a-r)}{17} > 0 \quad \forall\, i \in \{A, B\}. \tag{1.11}$$

Moreover, the appendix [(A.3)] shows that welfare continuously falls in each country if the foreign ownership share is increased (i.e., if α falls). For a fully diversified ownership structure we get

$$W^i_{(DD)}\big|_{\alpha=0.5} = \frac{132}{289}\,(a-r)^2 < W^i_{PO} \quad \forall\, i \in \{A, B\}. \tag{1.12}$$

Finally, we report the profits of each firm in the double duopoly equilibrium, given the governments' tax choices for $\alpha = 1$ and $\alpha = 0.5$. From (A.2) these are given by

$$\pi_{j(DD)}\big|_{\alpha=1} = \frac{(a-r)^2}{8}, \quad \pi_{j(DD)}\big|_{\alpha=0.5} = \frac{9(a-r)^2}{289} \quad \forall\, j \in \{1, 2, 3, 4\}. \tag{1.13}$$

Hence profits of each firm fall when the foreign ownership share rises. This is due to the higher taxes that each government levies, due to the tax exporting effect.

[17] Recall that the quantities supplied to each market are well defined in our segmented markets model (see footnote 9). The result that non-cooperative commodity taxation under the origin principle yields a first-best outcome is known from the previous tax literature (Keen and Lahiri, 1998, Proposition 6; Haufler at el., 2005). This literature also shows that the result holds for more general cost and demand functions, as long as the two countries are symmetric.

Summarizing our results in this section gives:

Proposition 1 *With symmetric countries and under a market structure of double duopoly, non-cooperative tax policies by national governments achieve the first best if all firms are fully owned by domestic residents. An increase in the share of foreign firm ownership raises tax rates in both countries above their Pareto efficient levels and reduces welfare in each country.*

1.4 National merger

This section develops the implications of a national merger proposal in country A. Firms 1 and 2 would thus merge to a new entity 12, which behaves as a single player. A core motivation for firms to undertake mergers, and an important reason for regulation authorities to permit them, is that mergers can create synergy effects.[18] In the following we thus assume that a national merger between firms 1 and 2 reduces the unit production costs by $\sigma \geq 0$. This implies that the production function changes to $x_j = k_j r/(r-\sigma)$ and the unit costs of production before taxes fall to $r-\sigma$. The merged firm takes these lower costs into account when solving its maximization problem (1.3). Governments set taxes so as to maximize national welfare, anticipating the optimal output decision of firms.[19] The appendix derives the resulting Nash equilibrium tax rates for varying levels of the foreign ownership parameter [see eq. (A.9)]. As before, our discussion focuses on the polar cases of $\alpha = 1$ and $\alpha = 0.5$.

1.4.1 National ownership of firms

For $\alpha = 1$ the optimal tax rates in (A.9) reduce to

$$t^A_{(NM)}\big|_{\alpha=1} = -\frac{1}{2}(a-r) - \frac{11}{10}\sigma, \quad t^B_{(NM)}\big|_{\alpha=1} = -\frac{1}{4}(a-r) - \frac{3}{20}\sigma. \tag{1.14}$$

[18] Röller et al. (2001) distinguish between different sources of efficiency gains following a merger such as rationalization, economies of scale, technological progress, purchasing economies, and reduction of slack. They also provide some empirical evidence of savings in variable cost associated with mergers.

[19] Market size must be sufficiently large in order to keep all firms in the market. In the benchmark case of full national ownership, for example, we must assume that $a > (9/5)\sigma + r$.

Let us first compare these tax rates to the double duopoly benchmark when there are no cost savings of the merger ($\sigma = 0$). It is then seen that the subsidy to domestic production is doubled in country A, and remains unchanged in country B [cf. eq. (1.9)]. The reason for the change in country A's tax policy is that both the *efficiency* and the *market share effect* increase from the perspective of this country. This is explained as follows. In the double duopoly benchmark, if country A grants a subsidy to one of its firms, then not only the foreign firm in B but also the second firm in A will react with a reduction of output under Cournot conjectures.[20] This reduces the effectiveness of subsidies when a country hosts two (or more) firms. When the two firms merge, the incentive to use subsidies is thus increased both in the home market (by the efficiency effect) and in the foreign market (by the market share effect). As a result of the higher subsidy, production in country A will be the same before and after the merger in this country. This implies in turn that the incentives for tax policy in country B are unaffected by the merger.

With positive cost savings $\sigma > 0$, tax rates fall further in both countries (i.e. subsidies rise), and this effect is more pronounced in country A. This is because the merged firm 12 can achieve a higher market share due to its cost advantage, benefiting the representative consumer in country A by generating larger total output and higher profits. Hence the incentive for A's government to subsidize the firm's output rises from both the *market share* and the *efficiency effects*. The higher subsidy granted by country A in turn triggers a higher subsidy paid by country B to its local firms.

The resulting welfare levels for $\alpha = 1$ are derived in the appendix and are given by

$$\begin{aligned} W^A_{(NM)}\big|_{\alpha=1} &= \frac{1}{50}\left[25(a-r)^2 + 50(a-r)\sigma + 69\sigma^2\right] \ , \\ W^B_{(NM)}\big|_{\alpha=1} &= \frac{1}{50}\left[25(a-r)^2 + 63\sigma^2\right] . \end{aligned} \tag{1.15}$$

Comparing these welfare levels to those obtained in the double duopoly equilibrium [eq. (1.10)], we see that welfare levels are identical in *both* countries when cost savings are absent. Hence, when firms are fully owned by domestic residents, non-cooperative

[20] In a similar setting, Huck and Konrad (2004) label the reduced effectiveness of domestic subsidies due to the output reduction of rivalling home firms a 'cannibalization effect'.

tax policies will again be globally Pareto efficient. At first sight it is surprising that the asymmetric scenario of a national merger in country A causes neither global efficiency losses nor redistributive effects, even though equilibrium subsidy rates differ between the two countries. As our above discussion has shown, however, the different subsidy levels just offset the reduced number of firms in country A so that total production in each country is unchanged in comparison to the benchmark setting. Moreover, no redistributive effects between countries arise because the higher subsidies paid by country A's government accrue entirely to domestic residents. Equation (1.15) further shows that a fall in the unit production costs of the merged firm benefits both countries. Hence welfare in A and B strictly rises after the national merger, for any $\sigma > 0$.

1.4.2 Internationally diversified ownership structure

When the ownership of firms is fully diversified ($\alpha = 0.5$), equilibrium tax rates are [cf. eq. (A.9) in the appendix]

$$t^A_{(NM)}\big|_{\alpha=0.5} = \frac{3}{28}(a-r) + \frac{1}{28}\sigma, \quad t^B_{(NM)}\big|_{\alpha=0.5} = \frac{9}{56}(a-r) + \frac{3}{56}\sigma. \tag{1.16}$$

We start again with $\sigma = 0$. As in the double duopoly equilibrium, tax rates are positive for sufficiently high levels of foreign ownership because of the *tax exporting effect*. The basic trade-off for each country is that the efficiency and market share effects call for a domestic production subsidy, but this in turn causes an income transfer from domestic taxpayers to the foreign owners of local firms. With a national merger in country A, the trade-off becomes more severe for this country because the incentive to subsidize the merged firm is increased. In the Nash equilibrium, this leads to country A choosing a lower tax than country B. Equation (1.16) also shows that tax rates rise still further when $\sigma > 0$. This is in contrast to the sign that the cost savings parameter σ has in the optimal tax formulae when firms are fully owned by national residents [eq. (1.14)]. Intuitively, the cost savings lead to higher production and raise the incentives of governments to tax the corresponding profits accruing to foreigners.

National welfare in the case of full international ownership diversification is given by

$$
\begin{aligned}
W^A_{(NM)}\big|_{\alpha=0.5} &= \frac{1}{1568}\left[627(a-r)^2+754(a-r)\sigma+1227\sigma^2\right] \\
W^B_{(NM)}\big|_{\alpha=0.5} &= \frac{1}{1568}\left[741(a-r)^2+270(a-r)\sigma+1053\sigma^2\right]. \qquad (1.17)
\end{aligned}
$$

In the absence of any cost savings from the merger, the comparison with the double duopoly benchmark [eq. (1.12)] shows that country A loses from the national merger in its own country, whereas country B gains. As we have argued above, country A will choose a lower tax in the Nash equilibrium as compared to country B. This implies a redistribution of income from country A to country B because A taxes the foreign owners of its firm less highly than does country B.

We are now prepared to discuss the conditions under which a national merger in country A will be cleared by this country's regulation authorities. Our comparison of (1.17) and (1.12) has shown that country A's government should reject the national merger proposal in the absence of cost savings. Cost reductions caused by the merger will, however, increase both output and profits in country A and hence unambiguously benefit the representative consumer in this country. Hence there must be a critical value of cost savings above which the national merger is in the national interest of country A. For $\alpha = 0.5$ this critical cost reduction is $\sigma = 0.1015(a-r)$.

Finally, we have to discuss whether the merging firms also have an incentive to propose the national merger. The profits of the merged firm 12 are derived in the appendix as

$$
\pi_{12}\big|_{\alpha=1} = \frac{1}{2}\left(a-r+2\sigma\right)^2, \qquad \pi_{12}\big|_{\alpha=0.5} = \frac{1}{8}\left(a-r+3\sigma\right)^2. \qquad (1.18)
$$

Comparing (1.18) with (1.13) shows that the profits of the merged firm (π_{12}) exceed the sum of profits of firms 1 and 2 for either $\alpha = 1$ or $\alpha = 0.5$, even if cost savings are absent ($\sigma = 0$). This result is in sharp contrast to the well known analysis of Salant et al. (1983) who show that the formation of a merger is not privately profitable for the merging firms in a standard Cournot game with linear demands, unless the merged firm realizes a market share of at least 80 per cent. Here the merger *is* privately profitable, even though the merged firm controls a market share of only 50%. This is due to the increased output subsidy paid by country A in response to the change in market structure caused by the national merger.[21] Since profits are further rising in σ, a national merger will thus always be proposed by the merging firms. Our results for the national merger are summarized in:

Proposition 2 *(i) When all firms are fully owned by domestic residents ($\alpha = 1$), the national merger benefits both the merging firms and the representative consumer in country A for any positive level of cost savings.*
(ii) When firm ownership is fully diversified internationally ($\alpha = 0.5$), then national welfare will only be increased by a national merger when cost savings exceed a critical threshold of $\sigma \approx 0.1015(a - r)$.

1.5 Cross-border merger

We now consider an exogenous cross-border merger proposal between firm 1 in country A and firm 3 in country B. The international merger is associated with an exogenous unit cost reduction of $s \geq 0$. Due to the symmetric distribution of ownership shares, the merged entity 13 will be owned equally by the representative consumers of each state for all levels of α. Hence, a cross-border merger increases the regional diversification of firm ownership whenever $\alpha > 0.5$ holds strictly in the pre-merger situation.

We assume that the merged firm divides its production between the two countries. This assumption can be motivated by the presence of restructuring costs, which the merged firm would face if it closed down one production plant entirely.[22] Moreover, maintaining a production base in each country allows the firm to serve each market by local production. We thus assume that each plant owned by the merged firm serves the customers in the respective country only. Even though our model does not incorporate

[21] It is easily checked that, in the *absence* of taxes, positive cost savings are also needed for the national merger to be privately profitable in the present setting. These can be calculated from (1.8) and (A.5) in the appendix (setting $t^A = t^B = 0$), yielding a critical value of $\sigma \approx 0.0438(a - r)$.

[22] From a theoretical perspective, fixing the decision of the merged firm of where to produce avoids tax competition between the two countries for a firm that would otherwise be mobile internationally (cf. footnote 8). This makes the analysis of the cross-border merger comparable to the double duopoly and national merger scenarios, where the location of firms is also fixed.

transport costs, we can think of small unit costs for shipping goods abroad, which break the indifference of firm 13 as to which customers to serve from each production unit.[23]

The maximization problems of the three firms $j \in \{13, 2, 4\}$ in the last stage of the game are similar in structure to eq. (1.3), but the problem of firm 13 must account for the fact that taxes continue to be paid in the country of production and hence different parts of its output are taxed in different countries. The equilibrium values for outputs, profits and consumer surplus, and the resulting welfare maximization problems of governments are found in the appendix.

1.5.1 National ownership of non-merged firms

With full domestic ownership of all non-merged firms ($\alpha = 1$) the symmetric equilibrium tax rates derived in the appendix [eq. (A.13)] are

$$t^A_{(IM)}\big|_{\alpha=1} = t^B_{(IM)}\big|_{\alpha=1} = -\frac{5}{23}(a-r) + \frac{9}{23}s\ . \tag{1.19}$$

Hence both countries grant an inefficiently low subsidy in this case, relative to the double duopoly benchmark. The main reason for this finding is that a *tax exporting effect* is now also present for $\alpha = 1$. While all firms are domestically owned prior to the merger, the ownership of the merged firm is shared between residents of countries A and B. This creates an incentive in both countries to increase taxes above their Pareto efficient levels.[24] Equation (1.19) shows that this tax exporting motive is even strengthened when the internationally merged firm commands of cost advantages relative to its national competitors, and hence captures larger market shares.

These taxes result in the following welfare levels for each country (see the appendix)

$$W^A_{(IM)} = W^B_{(IM)}\big|_{\alpha=1} = \frac{1}{1058}\left[525(a-r)^2 + 318(a-r)s + 689s^2\right]. \tag{1.20}$$

[23] The argument that cross-border mergers lead to savings in transport costs is stressed in the existing literature. See e.g. Horn and Persson (2001), or Südekum (2008).

[24] Note that the efficient post-merger tax would even be lower (the subsidy would be higher) than in the double duopoly benchmark, due to increased market concentration.

In the absence of cost savings ($s = 0$), welfare in each country is now lower than in the Pareto efficient double duopoly benchmark. This is of course due to the governments' strategic tax exporting motive discussed above. However, synergy effects will benefit consumers in each country. From (A.3) and (1.20) we find that welfare in the international merger equilibrium will reach the benchmark level under double duopoly when $s \approx 0.0123(a - r)$.

1.5.2 International ownership of non-merged firms

When the ownership shares of non-merging firms are also fully diversified, Nash equilibrium tax rates after the international merger are [see eq. (A.13)]

$$t^A_{(IM)}\Big|_{\alpha=0.5} = t^B_{(IM)}\Big|_{\alpha=0.5} = \frac{3}{31}(a - r) + \frac{1}{31}s. \tag{1.21}$$

Focusing on the case without cost savings ($s = 0$), these tax rates are again positive, but they are lower than in the double duopoly benchmark (cf. (1.11)). Moreover, a comparison with eq. (1.16) shows that taxes in *both* countries are lower after the cross-border merger, as compared to the national merger. Since we know that tax rates are above their Pareto efficient levels in the presence of foreign firm ownership, this implies that global welfare must also be higher for the international merger. Moreover, taxes rise less strongly in response to cost savings than is true under the national merger.

To explain these results, observe first that the profits of all firms are equally shared between residents from A and B. Hence the *tax exporting effect* is equally strong in the national and international merger scenarios when $\alpha = 0.5$. Moreover, with equally shared ownership of all firms, the *market share effect* is absent [see eq. (1.5)]. Hence any tax differences in the two scenarios must be driven by the *efficiency effect.* This effect will be the stronger the larger is the part of domestic consumption that is also produced domestically (as governments ultimately aim at increasing domestic consumption, but can only subsidize production). This share is higher under the cross-border merger, as compared to the national merger, when the merged firm 13 maintains production in both countries and thus produces its output in countries A and B for the respective local consumers only. In other words, the effect of the international merger between firms 1 and 3 is to substitute local production for the exports that these firms undertook in the pre-merger equilibrium. This aligns the tax incentives of governments more closely with the requirements of Pareto optimality and lowers tax rates in both countries.

National welfare after the cross-border merger is given by (see the appendix)

$$W^A_{(IM)} = W^B_{(IM)}\big|_{\alpha=0.5} = \frac{1}{1922}\left[861(a-r)^2 + 574(a-r)s + 1377s^2\right]. \tag{1.22}$$

Comparing (1.22) to the corresponding value in the double duopoly benchmark [eq. (1.12)] shows that national welfare after the international merger falls below the welfare in the double duopoly benchmark when $s = 0$. This is because the lower equilibrium tax rates in the international merger scenario are insufficient to compensate consumers for the reduced number of competing firms. On the other hand, cost savings again have a direct, positive effect on welfare in both countries. For $\alpha = 0.5$, the critical cost savings of the international merger that make the resident of each country equally well off as compared to the double duopoly case are $s \approx 0.0273(a-r)$. This threshold is lower than the corresponding value in the national merger scenario, due to the more efficient tax choices of governments.

Finally, we have to evaluate the incentive of firms to engage in a cross-border merger. The profits of the merging firm 13 are derived in the appendix and are given by

$$\pi_{13}\big|_{\alpha=1} = \frac{1}{8}\left[\frac{532(a-r)+1140s}{437}\right]^2, \quad \pi_{13}\big|_{\alpha=0.5} = \frac{1}{8}\left[\frac{756(a-r)+2484s}{837}\right]^2. \tag{1.23}$$

Comparing these values with the pre-merger profits in eq. (1.13) shows that the international merger will not be profitable for the merging firms unless there are noticeable cost savings. One reason is again that countries will tax all firms more severely when an international merger raises the foreign ownership share of domestic firms. This difference to the double duopoly case is most pronounced when all firms were nationally owned prior to the international merger. Hence the critical value of cost savings that makes firms willing to engage in an international merger is $s \approx 0.0754(a-r)$ for

$\alpha = 1$, but only $s \approx 0.0320(a - r)$ for $\alpha = 0.5$.[25] Both of these values are higher than the cost savings required by regulation authorities. Therefore, the incentives of the merging firms are now the binding constraint for an international merger to be enacted. This contrasts with the national merger case and results from the fact that the merging parties do not benefit from a more favorable tax environment, relative to their competitors, in the international merger scenario. Importantly for our ensuing analysis, it remains true that, for $\alpha = 0.5$, the binding threshold value of cost savings is lower for the cross-border merger, as compared to the national merger. Our results are summarized in:

Proposition 3 *A cross-border merger will benefit the merging firms only if it delivers strictly positive cost savings. The critical value of cost savings is lower the more firm ownership is diversified in the initial equilibrium and given by* (i) $s \approx 0.0754$ *when all firms are fully owned by domestic residents* ($\alpha = 1$)*; and* (ii) $s \approx 0.0320(a - r)$ *when firm ownership is fully diversified internationally* ($\alpha = 0.5$)*.*

1.6 When does each type of merger occur?

Having described the national and international merger scenarios in isolation, it is straightforward to infer under which conditions one or the other type of merger is more likely to occur. For this comparison we make the critical assumption that cost savings are the same in the two scenarios, i.e. $\sigma = s$. Table 1.1 summarizes the critical values of cost savings needed for (i) merging firms to propose the merger and (ii) governments to clear it, for each of the different types of merger and for different values of the initial foreign ownership share α.

[25] In the absence of taxes, the critical cost savings needed for the merger to be profitable for the merging firms are the same as in the national merger case and equal $s \approx 0.0438(a-r)$ (cf. footnote 21). This value lies in between the two critical values with taxes and polar assumptions about α.

Table 1.1: Critical values of cost savings in different merger scenarios

National merger	$\alpha = 1$	$\alpha = 0.5$
(i) merging firms	0	0
(ii) governments	0	$0.1015(a-r)$
binding value	0	$0.1015(a-r)$
Cross-border merger	$\alpha = 1$	$\alpha = 0.5$
(i) merging firms	$0.0754(a-r)$	$0.0320(a-r)$
(ii) governments	$0.0123(a-r)$	$0.0273(a-r)$
binding value	$0.0754(a-r)$	$0.0320(a-r)$

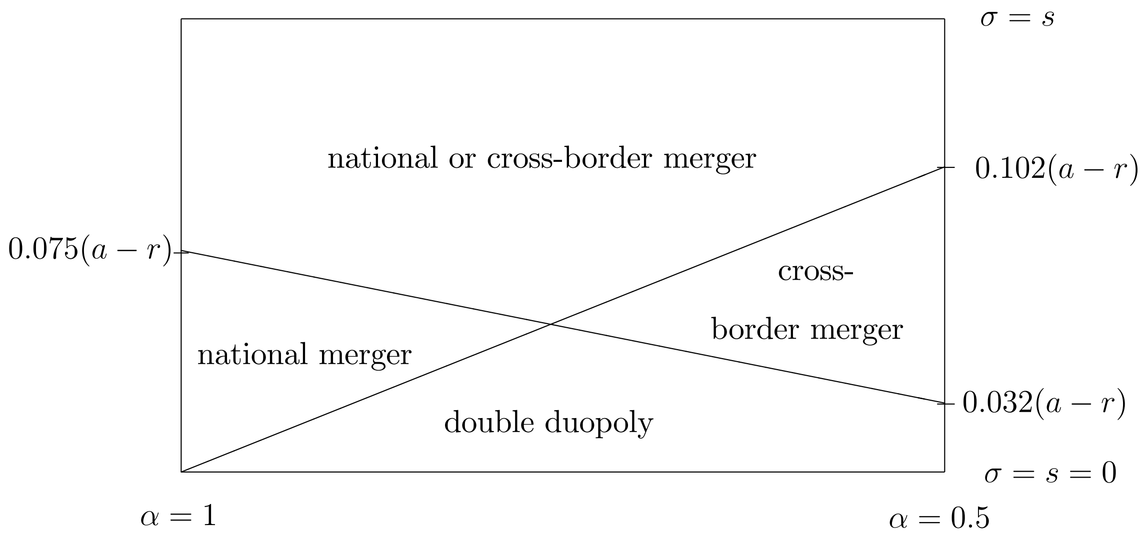
From Table 1.1 we then immediately arrive at:

Proposition 4 *In comparison to a national merger, a cross-border merger* (i) *requires higher cost savings to be proposed and cleared when there is full national ownership in the pre-merger equilibrium* ($\alpha = 1$)*;* (ii) *requires lower cost savings to be proposed and cleared when the pre-merger equilibrium is characterized by full international ownership diversification* ($\alpha = 0.5$)*.*

With full domestic ownership of firms ($\alpha = 1$) the national merger is the preferred alternative, as *any* positive level of cost savings will ensure that the merger benefits all the parties involved. In contrast the international merger will cause overtaxation of profits due to a *tax exporting effect.* With full international ownership diversification ($\alpha = 0.5$), however, this result is reversed. The critical value of cost savings at which the national merger will be proposed and cleared is now higher than under the cross-border merger. There are two reasons for this. First, the *tax exporting effect* is now equally strong in the two merger scenarios and no longer constitutes a disadvantage for the international merger. Second, the *efficiency effect* is stronger in the international merger case, because a higher share of consumption in each country is also produced locally and subsidies can be targeted more effectively. Hence taxes in both countries will be lower and closer to their efficient levels, as compared to the national merger.

Our findings are graphically summarized in Figure 1.1. The figure shows that if cost savings are small (and α is substantially less than 1), neither a national nor an international merger will simultaneously benefit the merging firms and the host

Figure 1.1: Equilibrium market structure with at most one merger



country. Hence a double duopoly situation is the equilibrium outcome in this case.[26] Conversely, for very high levels of $\sigma = s$, either the national or the international merger will be proposed and cleared. The interesting cases lie in between. For high levels of α there is an intermediate range of cost savings for which the national merger, but not the international merger, is simultaneously profitable for the merging firms and for country A's government. For low levels of α there is instead a range of cost savings where the international merger is proposed and cleared, whereas the national merger is blocked by the host country's regulation authority. Our detailed intuitive discussion of the relevant effects in the previous sections suggests that the qualitative pattern of results shown in Figure 1.1 should carry over to more general settings (for example, with respect to the specifications of utility and cost functions), although the exact location of the different areas in the figure will of course change.

Finally we briefly discuss how the size of the different areas in Figure 1.1 will be affected when some of the model assumptions are relaxed. A first relevant extension is to introduce trade costs between countries A and B. This implies that the output of each firm is larger for the domestic than for the foreign market in the initial double duopoly equilibrium. Moreover, a cross-border merger eliminates trade costs for the

[26] Note that the term 'equilibrium' has a narrow meaning in our analysis, as at most one merger can occur.

merging firm and thus adds a second element of efficiency gains, in addition to the reduction of unit production costs. Other things being equal, this will make it more profitable for firms to propose a cross-border merger, leading to a downward shift of the downward sloping curve in Figure 1.1. As a result the parameter range where a cross-border merger is the equilibrium market structure would be enlarged.

Another possible extension is to relax the assumption that governments have lump-sum tax instruments at their disposal and assume instead that the shadow price of public funds is exogenously fixed at a value in excess of unity. In this case optimal taxes will generally be higher than in our benchmark case, as the value of positive tax revenues is increased. Since a merger increases market concentration and accordingly calls for higher subsidies on account of the *efficiency effect*, an increase in the shadow cost of public funds will make it less likely for governments to clear a merger proposal. However, the government's willingness to clear the merger is the binding constraint only in the case of a national merger (cf. Table 1.1). Therefore, the only first-order effect in this case is to shift the upward sloping line in Figure 1.1 to the left. Hence this extension would also increase the parameter range for which the cross-border merger is the equilibrium market structure.

1.7 Conclusions

In many industries governments have sector-specific tax and regulation policies at their disposal to influence the market outcome after a change in market structure has occurred. In this paper we have set up a simple model to analyze the incentives for nationally optimal tax policies in response to a national merger on the one hand, and to a cross-border merger on the other. Whether these different tax responses favor a national or an international merger depends crucially on the share of foreign firm ownership in the pre-merger situation. If all firms are locally owned initially, then the national merger leads to efficient tax policy choices and requires fewer cost savings, in comparison to the cross-border merger, in order to be enacted. In contrast, if the share of foreign firm ownership is large initially, then the international merger will be proposed and cleared for a wider range of cost savings.

Our model thus implies that a rise in international portfolio diversification will raise the likelihood of cross-border mergers, other things being equal. This pattern is compatible with some of the examples mentioned in the introduction. The French firm *Alstom*, whose international takeover was blocked by the French authorities, has a high share of national ownership until today, with French shareholders possessing 54% of *Alstom*'s capital in 2009. This is at least partly in contrast to the ownership structures of the German firm *RWE* where foreign institutional shareholders were the dominant group in 2009, comprising 64% of all institutional shareholders. By the time *RWE* acquired the British energy company *Innogy* in 2002, its ownership had already diversified substantially and the same was true for the British target firm, which was almost exclusively owned by private individuals at the time of the takeover. Overall, these examples fit the implication of our model that a large share of foreign asset holdings promotes international instead of national mergers. Our argument is complementary to other reasons for cross-border mergers, in particular the possibility to save on aggregate transport costs.

The findings in this paper hold the testable empirical implication that we should observe a positive relationship between the foreign ownership share and the share of cross-border mergers in a particular industry. There is indeed some first, suggestive evidence in support of this proposition. In the OECD countries the share of cross-border mergers in the total number of $M\&A$ cases differs widely across different economic sectors and is highest in manufacturing (about 35%; see Focarelli and Pozzolo, 2001, Table 1). At the same time, manufacturing is also one of the most internationalized sectors with respect to foreign ownership, at least in European countries (about 25%; see Denis et al., 2005, Figure 4.2). Similarly, there are sectors with a low share of foreign firm ownership, such as construction, where the share of cross-border mergers in the total number of $M\&A$ cases is also low. A detailed empirical study would be needed to rigorously test whether this positive relationship between foreign ownership and the share of cross-border mergers holds more generally, and whether tax and regulatory policies play an important role in this process.

Our theoretical analysis could be extended in several directions. One possibility would be to endogenize the share of foreign firm ownership, and relate this share explicitly to the forces of economic integration. In such a setting international portfolio diversification would lead to gains in the form of higher returns or lower aggregate risk, but it would also cause higher information or transaction costs. If economic integration reduces the latter, the link between globalization and the rise of cross-border mergers could be explicitly modeled. Another extension would be to consider endogenous merger equilibria, which treat mergers as a cooperative game of coalition formation. These extensions could also be combined to study how increasing economic integration affects the equilibrium ownership structure of firms when the optimal adjustment of tax policies is simultaneously taken into account.

Chapter 2

Merger policy and tax competition: the role of trade costs

2.1 Introduction

Trade barriers still play an important role in international markets although there have been serious attempts to lower them over the last decades. In fact, trade liberalisation on a worldwide level has taken place especially within the scope of the World Trade Organisation (WTO) based on the General Agreement on Tariffs and Trade (GATT). Nevertheless, the last attempt to overcome existing trade barriers and to lower persisting tariffs in the so called Doha Development Agenda has not been successful so far. This is noteworthy as the failure to finalise the Doha Development Agenda in 2008 has prohibited a significant increase of trade volume and trade cost savings[27]. Conversely, trade costs can still play a significant role in firms' decision making although unit transportation costs have become very low for most products[28]. Moreover, trade barriers as a potentially important amount of trade costs are often prevalent in sectors with concentrated industries, e.g. in the aerospace industry.

I will deal in this chapter with trade costs in concentrated industries where firms

[27]Global income gains might be around 160 billions of US dollars if the proposals of the Agenda were implemented, compare estimates of the worldbank e.g. Hoekman et al (2009).

[28]Anderson and Wincoop (2004) survey the measurement of trade costs and show that they are still highly relevant despite of the trend to globalisation: the ad valorem tax equivalent often exceeds 100%.

might consider cross-border merging activities. The value of cross-border mergers and acquisitions has seen an enormous increase over the last decades reaching about one trillion US dollars in the record year 2007 (see UNCTAD World Investment Report 2009, annex table B.4). In some countries there are even more international mergers and acquisitions than domestic deals[29]. One motivation to engage in international mergers and acquisitions can be the implied ability to serve foreign markets directly without any trade costs if merged firms produce in each market. I will consider in this chapter horizontal mergers where this inherent tariff jumping argument (and trade costs in general) has to be considered.

Merger proposals in concentrated industries must be regularly cleared by (inter)national competition authorities or governments that are, at least ideally, interested in maximizing (inter-)national welfare. Moreover, national governments often have another instrument at their disposal: they can adjust their sector specific taxes or subsidies to new market structures. More generally, sector specific tax or subsidy policies might also be implemented by more or less severe regulation policies that exist, for example, in most network industries. This contribution raises the question how welfare and profits are affected by a cross-border merger if national governments indeed use these two instruments, merger control and sector specific taxes. The main focus lies on the specific role of trade costs with respect to the welfare maximizing behaviour of national governments and on the incentives of firms to pursue a cross-border merger.

Therefore I introduce a simple model of Cournot-competition on two segmented and symmetric markets with two producing firms in each market. Essentially there is costly trade between these markets. I apply a three stage game where governments decide on a proposed merger on the first stage. On the second stage governments choose national welfare maximizing tax rates anticipating the final output decisions of the firms. This order of the game can be motivated by the long-term implications of mergers whereas tax rates or regulation policies can often be adjusted in the short-term. Finally, the chapter shows that governments choose lower tax rates as soon as trade costs shrink. The main reason is that lower trade costs make it more attractive to generate market shares abroad which can be favorised by lower taxes or even higher subsidies. This

[29] See e.g. Rossi and Volpin (2004), table 1.

even leads to the potential implementation of the first best in concentrated industries if there are no trade costs (and no costs of taxation). Conversely, governments have an incentive for overtaxation if there are positive trade costs. Comparing the pre-merger to the post-merger situation, we will see that there is a higher incentive for overtaxation if a cross border merger has taken place which, in turn, renders international merger proposals unprofitable from the perspective of the merging firms in this simplified model. With respect to the final decision on a merger proposal, it will be shown that mergers which become privately profitable due to additional synergies would also be welfare increasing.

The presented model is closely related to Haufler/Schulte (2009) who have also investigated the interactions between merger policy and tax competition. The distinguishing feature of the contribution at hand is the introduction of trade costs between countries[30]. Moreover, it is related to several strands of the literature. First, there is a literature on strategic merger policy in open economies. Examples are Huck and Konrad (2004), Saggi and Yildiz (2006) and Südekum (2008) who all discuss the interrelation between competition and trade policy but not with tax policies. Other papers focus on the impact of trade costs on firms' profits and merging decisions but again without consideration of tax policies: Hijzen et al. (2008) for example show, using OECD data from 1990-2001, that the impact of trade costs on cross-border mergers is negative which might be due to obstructive trade barriers. Nevertheless this effect is less negative for horizontal mergers which is consistent with the tariff-jumping argument. Finally, my paper builds on optimal commodity taxation in concentrated industries. An early contribution of this literature is Keen and Lahiri (1998) who are among the first authors focussing on oligopolistic industries in this context[31].

This chapter is organised as follows: section 2.2 introduces the model by distinguishing between the benchmark scenario in the pre-merger situation and the cross-border scenario in the post-merger situation. The results of the model are left to section 2.3. Open issues are discussed in section 2.4. Finally, conclusions are drawn in section 2.5.

[30] Haufler and Schulte (2009) have focused on firm ownership with respect to their international diversification.

[31] More recent papers are Haufler et al. (2005) and Hashimzade et al. (2005).

2.2 Model

In this section I will present the theoretical framework which enables us to analyse the attractiveness of mergers and their welfare effects in the context of tax competition under the special emphasis of existing trade costs between countries.
Before specifying the analytical assumptions, I start with defining the timing of the game used in the model. The game structure is in line with the analysis in Haufler and Schulte (2009)[32]. In the first stage, firms decide if they want to pursue a merger, especially an international one. Depending on its welfare implications, regulation authorities may accept or deny such a merger proposal. In the next stage, governments non-cooperatively set production based tax rates. These taxes will be unit taxes on production and thereby affect the output decisions of the profit maximizing firms on the last stage of the game.
I start with the benchmark case that describes the pre-merger situation in an oligopolistic industry of four firms which are operating in two countries.

2.2.1 Benchmark without cross-border merger

Consider two symmetric countries A and B with two firms located in each country. These firms are producing a homogenous good, for example electricity. It is sold in both markets whereby each firm maximizes its profit independently in each market[33]. Firms are facing a constant production cost r which is resulting of the normalization that each firm is able to produce one unit of output by using one unit of capital[34]. Moreover they have to bear a sector specific unit tax of production, which is levied due to the origin principle of taxation. Taxation in the country of production is relevant if we consider profit taxes or subsidies that are targeted directly at local producers. In contrast to HS, who are dealing with a similar setting, I add transport costs of k per unit of production that is delivered to the respective foreign market[35]. The focus in this chapter will be

[32] I refer to Haufler and Schulte (2008) by denoting HS in the following.
[33] Therefore markets are assumed to be segmented. This is often plausible in formerly unprivatised sectors (as in the energy sector) because some national structures are still prevailing there.
[34] Capital is available at the exogenous world interest rate r.
[35] Note that there will be two-way trade of the homogenous good due to reciprocal dumping, see Brander and Krugman (1983).

on the analysis of the resulting implications due to these transport costs which can, generally spoken, be interpreted as a parameter of international integration. On the demand side I assume a quadratic, quasi linear utility U of the representative consumer such that income effects are only present with respect to an additional numeraire good z. This generates a linear inverse demand constituting a manageable analytical workhorse model.

Let us assume that firms 1 and 2 are producing in A and firms 3 and 4 are producing in B. I denote production of firm i for market A as x_i and for market B as y_i. Formally I have $U_A(x,z) = u(x) + z$ with $x = \sum_{i=1}^{i=4} x_i$ in country A and $U_B(y,z) = u(y) + z$ with $\sum_{i=1}^{i=4} y_i$ in country B. This leads to the linear inverse demand $p_A = a - x$ and $p_B = a - y$.

The model is solved by backward induction. Therefore I start by considering the profit maximization problems of the four firms in the last stage of the game. Beside the original production cost r, firms have to bear the tax rate t levied on every unit of production in the producing country and trade costs k if the produced unit has to be delivered to the foreign market. Therefore I get the following total production cost c_i:

$$\begin{aligned} c_i &= x_i(r + t_A) + y_i(r + t_A + k) \qquad \forall\, i \in \{1,2\} \\ c_i &= x_i(r + t_B + k) + y_i(r + t_B) \qquad \forall\, i \in \{3,4\} \end{aligned} \tag{2.1}$$

This leads immediately to the profit maximizing problems of the firms:

$$\begin{aligned} \max_{x_i,y_i} \pi_i &= \left(a - \sum_{i=1}^{i=4} x_i\right) x_i + \left(a - \sum_{i=1}^{i=4} y_i\right) y_i - x_i\,(r + t_A) - y_i\,(r + t_A + k) \\ \forall\, i &\in \{1,2\} \end{aligned} \tag{2.2}$$

$$\begin{aligned} \max_{x_i,y_i} \pi_i &= \left(a - \sum_{i=1}^{i=4} x_i\right) x_i + \left(a - \sum_{i=1}^{i=4} y_i\right) y_i - x_i\,(r + t_B + k) - y_i\,(r + t_B) \\ \forall\, i &\in \{3,4\} \end{aligned}$$

I assume to have segmented markets in A and B which is at least plausible in some industries under consideration[36]. Thereby firms will optimize their output decisions separately with respect to the two markets. Following this, I get the Nash equilibrium quantities for country A which are symmetric in country B:

$$\begin{aligned} x_i &= \frac{1}{5}(a-r)+\frac{2}{5}k-\frac{3}{5}t_A+\frac{2}{5}t_B \qquad \forall\ i\in\{1,2\} \\ x_i &= \frac{1}{5}(a-r)-\frac{3}{5}k+\frac{2}{5}t_A-\frac{3}{5}t_B \qquad \forall\ i\in\{3,4\} \\ x &\equiv \sum x_i=\frac{4}{5}(a-r)-\frac{2}{5}(k+t_A+t_B) \end{aligned} \tag{2.3}$$

The implied price level, profits and consumer surplus of both countries are found in the appendix. Governments in A and B seek to maximize social welfare W consisting of consumer surplus (CS)[37], profits of domestic firms and tax revenue by choosing an optimal production tax (or subsidy). They are faced with the following optimization problem:

$$\begin{aligned} \max_{t_A} W_A &= CS_A+\pi_1+\pi_2+t_A\left(x_1+x_2+y_1+y_2\right) \\ \max_{t_B} W_B &= CS_B+\pi_3+\pi_4+t_B\left(x_3+x_4+y_3+y_4\right) \end{aligned} \tag{2.4}$$

The resulting optimal tax rates and its implications on profits and welfare of this benchmark scenario will be discussed in the next section. They will be compared to the results of an international merger scenario to which I turn now.

2.2.2 Cross-border merger

Let's assume that two firms (firms 1 and 3) perform an international merger building the new entity f. The merged firm may produce in both countries or shut down one production facility. This decision will depend on the corresponding impact on profits[38]. Therefore we have to compare the resulting unit cost of production in both countries. Considering the offer in the segmented market A, firm f wants to produce

[36] Thereby, due to the symmetry of the model, price discrimination does not occur in equilibrium.

[37] $CS_A = CS_B = \frac{1}{2}(a-x)x$

[38] This is in contrast to HS who do not allow the international merged firm to choose their production facility.

the respective quantity in country A if the unit tax rate in this country is smaller than the unit tax rate in B plus additional unit trade costs k. Therefore, f produces in A for A if $t_A < t_B + k$ holds.
Analogously, production for market B of the international merged firm takes place in country B if the condition $t_B < t_A + k$ is satisfied. If these conditions for home-market production are fulfilled simultaneously, the profit maximizing problem of the firms can be stated as follows :

$$\begin{aligned}
\max_{x_f, y_f} \pi_f &= (a - x_f - x_2 - x_4)\, x_f - x_f\,(r + t_A) \\
&\quad + (a - (y_f + y_2 + y_4)\, y_f - y_f\,(r + t_A) \\
\max_{x_2, y_2} \pi_2 &= (a - x_f - x_2 - x_4)\, x_2 - x_2\,(r + t_A) \\
&\quad + (a - (y_f + y_2 + y_4))\, y_2 - y_2(r + t_A + k) \\
\max_{x_4, y_4} \pi_4 &= (a - x_f - x_2 - x_4)\, x_4 - x_4\,(r + t_B + k) \\
&\quad + (a - (y_f + y_2 + y_4))\, y_4 - y_4\,(r + t_B)
\end{aligned} \tag{2.5}$$

Again, firms will optimize their output decisions separately with respect to both markets as they are assumed to be segmented. The resulting quantities are dependant on transport costs and on tax rates at home and abroad. Thereby, home market production is increasing with transport costs which generates an advantage for the merged firm as it is the only one producing in both countries. As expected, production is negatively affected by the local tax rate and positively affected by the foreign tax rate. These quantities are as follows with respect to market A (market B is again symmetric):

$$\begin{aligned}
x_2 &= x_f = \frac{1}{4}(a-r) + \frac{1}{4}k - \frac{1}{2}t_A + \frac{1}{4}t_B \\
x_4 &= \frac{1}{4}(a-r) - \frac{3}{4}k + \frac{1}{2}t_A - \frac{3}{4}t_B \\
x &= \frac{3}{4}(a-r) - \frac{1}{4}k - \frac{1}{2}t_A - \frac{1}{4}t_B
\end{aligned} \tag{2.6}$$

The resulting prices, profits and consumer surplus can be found in the appendix again.

Anticipating firms' behaviour, governments of country A and B execute a non-cooperative tax competition game by choosing the tax rate that maximizes national welfare:

$$
\begin{aligned}
\max_{t_A} W_A &= CS_A + \frac{1}{2}\pi_{13} + \pi_2 + t_A(x_f + x_2 + y_2) \\
\max_{t_B} W_B &= CS_B + \frac{1}{2}\pi_{13} + \pi_4 + t_B(y_f + y_4 + x_4)
\end{aligned} \tag{2.7}
$$

It can be shown that the only potential equilibrium is in fact an equilibrium with production of the merged firm in both countries for the respective home market (see appendix). Thereby, governments must be faced with sufficient high trade costs such that there is no incentive to lower the tax rate in order to attract the mobile merged firm or to lower a subsidy in order to loose that firm. Therefore, trade costs must be assumed to be at least

$$k \geq \frac{4}{1861}(a-r)\left(23\sqrt{2626} - 1122\right) \equiv d\ . \tag{2.8}$$

The final results of the non cooperative tax competition game and its implications on optimal firms' behavior will be discussed in the following section.

2.3 Results

Again, let's start with the benchmark scenario without a merger in order to compare the results to the international merger scenario later on.

2.3.1 Benchmark without cross-border merger

In the benchmark scenario of two firms located in each country (double duopoly, DD), the final optimal tax rates, solving (2.4) are

$$t^A_{(DD)} = t^B_{(DD} = -\frac{1}{4}(a-r) + \frac{1}{8}k\ . \tag{2.9}$$

There are two effects at work calling for an optimal subsidy in this symmetric oligopoly such that the Pareto optimal quantity would be produced in the absence

of trade costs. On the one hand governments seek to maximize domestic consumer surplus by incentivising firms to produce as much as they would produce under perfect competition (*efficiency effect*): this incentive is limited in an open economy by the fact that governments do not internalize benefits accruing to foreigners buying subsidized products. On the other hand this limitation is counteracted by a *market share effect* describing the incentive for governments to generate relatively high market shares of domestic firms in the foreign market in order to increase their profits at the expense of foreign firms. The overall resulting Pareto-optimal quantity is identically to the one shown by HS if there were no trade costs[39]. Considering positive trade costs in this example of linear demand, these incentives do not lead to a Pareto optimal tax rate any longer. Obviously, trade costs give a cost advantage for local firms generating higher market shares for these firms. The increased home-market production is stimulating higher subsidies as a higher share of their benefits remains in the granting country now. Technically, one can show that the efficiency effect calling for higher subsidies is indeed increasing with k by introducing foreign ownership of firms. Assuming firms to be owned equally by domestic and foreign residents, there is no market share incentive for granting subsidies as profits are shared equally between countries anyway. In this case, the equilibrium tax rate becomes a decreasing function of trade costs k:
$t = \frac{2}{17}(a - r) - \frac{1}{17}k$[40]. Nevertheless, this increased efficiency effect is dominated by a decreased market share incentive such that there is the positive impact of k on t shown in equation (2.9). This is again explained by the competitive disadvantage of domestic firms in the foreign market due to trade costs: thereby subsidies, granted to generate higher market shares abroad, become less effective if trade costs increase inducing a lower trade volume. Essentially, higher subsidies would have a lower impact on profits earned by additional units sold in the foreign market (and therefore on social welfare) if exporting firms have to bear higher trade costs. The dominant market share effect can also be seen in the profit maximizing quantities [see eq. (2.3)] showing that quantities sold abroad decrease linearly with higher trade costs. This is only partly offset by a

[39] Compare HS, section 3. Moreover, Haufler et al. (2005), who compare different tax regimes, refer to this result of Pareto Optimality on page 290f.

[40] Moreover, the equilibrium tax rate has increased for a given level of k because there is an additional incentive to tax profits accruing to foreigners.

higher quantity produced in the home market[41]. These findings can be summarized in the following proposition:

Proposition 5 *National welfare maximizing governments choose higher production tax rates in the Nash equilibrium if trade costs increase. This tax rate is not Pareto-optimal in contrast to a situation without trade costs.*

Let's also have a closer look on the resulting equilibrium profits of the symmetric firms. This equilibrium can be computed by inserting (2.9) in (2.3):

$$\begin{aligned} x_1 &= x_2 = y_3 = y_4 = \frac{1}{4}(a-r) + \frac{3}{8}k && (2.10) \\ x_3 &= x_4 = y_1 = y_2 = \frac{1}{4}(a-r) - \frac{5}{8}k \\ x &= y = a - r - \frac{1}{2}k && (2.11) \end{aligned}$$

This leads to equilibrium profits by inserting these results in the respective profit equations in the appendix:

$$\pi_{j(DD)} = \frac{1}{8}\left(a - r - \frac{1}{2}k\right)^2 + \frac{1}{2}k^2 \quad \forall\, j \in \{1,2,3,4\} \tag{2.12}$$

It can be seen that profits decrease for low levels of k but will increase for high levels of k again[42]. This is explained by the parabolic form of total trade costs: they reach their maximum for intermediate levels of k as there is already a noticeable level of unit trade costs together with a still considerable trade volume. When k becomes even higher, these higher unit costs are mitigated by a lower trade level leading to shrinking total trade costs. This trade-off is not changed fundamentally by governments which are imposing higher tax rates whenever k increases because the implied tax change follows a linear pattern [see eq. (2.9)]. Moreover, there is a beneficial effect of increasing unit trade costs from the perspective of profit maximizing firms: an increase in k leads to a lower degree of competition which implies a decrease of total offer [see eq. (2.11)]

[41] Moreover, quantities must be nonnegative for a valid analysis. This is ensured if trade costs do not exceed $k = \frac{2}{5}(a-r)$.

[42] Recalling the maximum level of k for positive trade, the overall effect of trade costs will never be positive compared to a situation without trade costs.

and a price above marginal costs, $p = r + \frac{1}{2}k$. In sum, firms' profits are minimized if $k = \frac{2}{17}(a - r)$. Profits increase for higher levels of trade costs again without reaching the level without any trade costs at the maximum level of k for positive trade.

Finally, optimal national tax policies imply the following equilibrium welfare levels by inserting the results above in (2.4):

$$W^A_{(DD)} = W^B_{(DD)} = \frac{1}{2}(a - r)^2 - \frac{1}{2}(a - r)k + \frac{9}{8}k^2 \tag{2.13}$$

If trade costs were absent, welfare reaches the first best level implied by the Pareto-optimal tax rates of (2.9) inducing quantities as under perfect competition. Considering trade costs, equilibrium welfare reflects the changes of profits described above as well as changes in consumer surplus (see appendix) and tax revenue. Not surprisingly, consumer surplus must decrease for all allowed positive values of k because firms benefit from an increased monopolistic power implying higher prices. Therefore the equilibrium welfare level will always be below the first best for all allowed levels of k as this dead weight loss can never be equalized by higher profits or higher tax revenue. Again, welfare is minimized at intermediate levels of k due to the importance of inefficient trade in this area.

The results can be summarized in proposition 6:

Proposition 6 *With positive trade costs, national welfare maximizing governments cannot achieve the first best welfare by an optimal national tax policy. Welfare as well as profits are minimized for intermediate levels of trade costs.*

2.3.2 International merger

Turning to the international merger scenario, the welfare maximization problem described in (2.7) is solved by levying the following optimal tax rate:

$$t^A_{(IM)} = t^B_{(IM)} = -\frac{5}{23}(a - r) + \frac{11}{23}k \tag{2.14}$$

Starting with the assumption of costless trade ($k = 0$), the equilibrium tax rate increases compared to the benchmark scenario. This can be explained by the international ownership diversification in consequence of the international merger between firm 1 in country A and firm 3 in country B building the new entity f: this internationally merged firm f is owned equally by both countries leading to an incentive to tax profits accruing to foreigners.

Considering the impact of positive trade costs, national welfare maximizing governments are faced with adjusted incentives. Therefore note that the relative importance of domestically produced products increases less with higher trade costs in the international merger scenario than in the benchmark scenario[43], which can be seen by comparing the respective results shown in (2.6) and (2.3)[44]. This decreased market share response of domestic firms to changes in trade costs implies that governments have a lower incentive to grant subsidies to these firms for efficiency reasons as soon as trade costs rise (decreased *efficiency incentive* for subsidies). There are even more incentives to grant lower subsidies (or to levy higher taxes) compared to the benchmark case if trade costs increase: an increase of k generates a competitive advantage for the international merged firm. This is the only one that can avoid trade costs by producing in every country and therefore ends up with a higher market share in both countries. Recalling that the implied increase in profits of the international merged firm must be shared equally between both countries, there is an incentive to levy higher taxes in order to tax profits accruing to foreigners (or to shrink subsidies, respectively). Moreover, the competitive advantage of the merged firm is a competitive disadvantage for the other firms with respect to their willingness to export. Consequently, exports shrink with an increase of trade costs (with respect to an exporting firm) and governments must adjust their willingness to grant subsidies: there is a lower incentive for subsidies in order to favor higher market shares abroad now (lower *market share incentive*).

All incentives taken together, the optimal tax rate or production subsidy has become

[43] This is reasonable as there is only one firm left in each country that has to bear trade costs such that only this firm suffers from an increase of these trade costs. This implies also that the total offer in each country shrinks less in the international merger than in the double duopoly scenario as soon as trade costs rise.

[44] $\frac{d((x_f+x_2))}{dk}_{(IM)} < \frac{d((x_1+x_2))}{dk}_{(DD)}$ and $\frac{d(x_4)}{dk}_{(IM)} > \frac{d(x_3+x_4)}{dk}_{(DD)}$ holds for all allowed levels of k.

more sensitive to changes in trade costs: higher trade costs imply a relatively higher tax increase in the international merger scenario, $dt^i_{(IM)}/dk > dt^i_{(DD)}/dk$. Proposition 7 summarizes:

Proposition 7 *Optimal national tax policy reacts by a tax increase to higher trade costs in the international merger scenario. This tax response is higher than in the pre-merger situation due to a change of market shares of the home-producing firms and an internationalisation of the ownership structure.*

Inserting optimal tax rates (2.14) into (2.6) generates the following equilibrium quantities as long as the equilibrium condition (2.8) as well as the condition for positive trade are fulfilled[45]:

$$\begin{aligned} x_f &= x_2 = y_f = y_4 = \frac{7}{23}(a-r) + \frac{3}{23}k \\ x_4 &= y_2 = \frac{7}{23}(a-r) - \frac{20}{23}k \\ x &= y = \frac{21}{23}(a-r) - \frac{14}{23}k \end{aligned} \tag{2.15}$$

This in turn leads to profit levels equal to

$$\begin{aligned} \pi_{f(IM)} &= \frac{2}{529}\left(7a - 7r + 3k\right)^2 , \\ \pi_{2(IM)} &= \pi_{4(IM)} = \frac{98}{529}\left(a-r\right)^2 - \frac{238}{529}k\left(a-r\right) + \frac{409}{529}k^2 . \end{aligned} \tag{2.16}$$

How are profits affected by the international merger? Comparing $\pi_{f(IM)}$ to $\pi_{1(DD)} + \pi_{3(DD)}$ of [see eq. (2.12)], we see that the international merged firm does not benefit from their merging activity because we have $\pi_{f(IM)} < \pi_{1(DD)} + \pi_{3(DD)}$ for all allowed levels of k[46]. So firms in an oligopoly of four firms do not have an incentive for a merger motivated exclusively by trade cost savings in this oligopolistic model with linear demand. Therefore Salant's merger paradox showing the non-attractiveness of mergers in a standard Cournot-model[47] still applies here although firms have to bear

[45] In the international merger scenario, trade is positive if $k < \frac{7}{20}(a-r)$. Therefore the analysis is valid for $d < k < \frac{7}{20}(a-r)$.

[46] Recall $d < k < \frac{7}{20}(a-r)$.

[47] See Salant et al. (1983).

trade costs that they might overcome by an international merger. This result does not come as a surprise because tax policy responses to merging activities are considered. In fact, firms have to bear higher taxes if trade costs increase [recall eq. (2.14)] which counteracts pure trade cost savings. This influence of the response of optimal national tax policy on profits will again be discussed in the next chapter. Nevertheless, firms may have an incentive to pursue an international merger if this is associated with additional savings due to synergy effects. However, firms even need higher synergy effects if trade costs increase in the allowed area of k[48]. The reason lies again in the positive tax policy response on trade costs and, moreover, on the fact that higher trade costs already lead to higher profits in the original double duopoly at the minimum considered level of k.

Non-merging firms generate higher profits after the merger for relatively low levels of k fulfilling the minimum condition on k for an existing equilibrium [see condition (2.8)]. In this area, non-merging firms simply benefit from higher market concentration as the standard Cournot model predicts. Nevertheless, if trade costs become sufficiently high[49], these firms suffer from increasing taxes and competitive disadvantage due to their disability to avoid trade costs by production in each country such that their profits shrink.

The welfare implication of the above results can be calculated by inserting (2.15), the resulting consumer surplus (see appendix) and (2.16) in the welfare maximizing problem (2.7) yielding:

$$W_{A(IM)} = W_{B(IM)} = \frac{525}{1058}\left(a-r\right)^2 - \frac{189}{529}k\left(a-r\right) + \frac{362}{529}k^2 \tag{2.17}$$

Again, as in the double duopoly scenario, welfare is minimized for intermediate levels of k because there is still the highest volume of trade costs in this area (due to the trading non-merged firms now). Moreover, even if trade costs become relatively high (but are below their maximum value for positive trade), welfare will still be below its level in

[48] $d\left(\pi_{f(IM)} - \pi_{1(DD)} - \pi_{3(DD)}\right)/dk = d\left(\frac{2}{529}\left(7a-7r+3k\right)^2 - \frac{1}{4}\left(r-a+\frac{1}{2}k\right)^2 - k^2\right)/dk = \frac{865}{2116}(a-r) - \frac{8705}{4232}k < 0 \ \ \forall \ \ k \in \left[d; \frac{7}{20}(a-r)\right]$.

[49] The condition is $k > \frac{2}{9}(a-r)$.

the absence of trade costs. This can again be explained by the increased monopolistic power of firms if markets are less integrated due to higher trade barriers. Optimal national tax policy cannot avoid this welfare loss by implementing an appropriate tax scheme.

The most interesting question is now if an international merger improves welfare compared to the pre-merger situation: comparing (2.17) with (2.13) and respecting the minimum condition on trade costs (2.8), an international merger would be welfare increasing if trade costs fulfill the following condition:

$$W_{i(IM)} > W_{i(DD)} \quad if \quad k \in \left[d; \frac{2}{1865}(a-r)\left(23\sqrt{29}+151\right)\right] \tag{2.18}$$

Now, it is the avoidance of inefficient trade in the initial double duopoly setting that renders the international merger relatively welfare increasing for this moderate level of trade costs despite of the higher market concentration and an increased incentive for (over)taxation. Finally, national merger control authorities would approve an international merger proposal in this area but firms do not have any interest to pursue such a merger without further cost savings due to synergies, for example by the implementation of a joint overhead structure.

Let's turn to the question how national regulation authorities should react if the merging firms can indeed benefit from additional cost savings consequent to the merger. Assuming that these cost savings do not reduce variable unit production costs but some additional fixed costs, such an international merger proposal should always be approved in this symmetric setting: cost reductions which are necessary in order to render the international merger profitable are always higher than potential welfare losses without accounting for these additional profits[50]. See appendix for calculation details.

[50] Global welfare is analogously affected as national welfare in this symmetric setting. Therefore a supranational regulation authority would decide in line with national regulation authorities. Of course, this would be different if both countries differ in their market structure.

The final results of this section can be summarized in the following proposition:

Proposition 8 *An international merger is not profitable from the perspective of the merging firms without further synergies. In contrast, these mergers would increase national welfare if trade costs are moderate. If firms benefit from a merger due to additional cost savings generated by reduced fixed costs, welfare maximizing governments should always approve such a merger.*

2.4 Discussion

The previous sections have shown that a trade avoiding international merger might be in the interest of welfare maximizing regulation authorities in the presented oligopolistic setting of Cournot-Competition. Nevertheless it always diminishes profits of the involved firms in the defined area of trade costs if there are no further synergies. Before considering the impact of lower or higher trade costs, it is worth highlighting that this result is partly driven by the tax policy response of national governments. Therefore let's consider a situation where governments have committed themselves to stick to the production tax rates in the benchmark scenario shown in (2.9) even if an international merger takes place. In general, the difference in profits before and after the international merger can be stated as follows using the respective equations in the appendix:

$$\begin{aligned}\pi_f - (\pi_1 + \pi_3) &= \frac{1}{400}(-14(a-r)^2 + 2(a-r)(82k + 7(t_A + t_B)) \\ &\quad -82k(t_A + t_B) + 568t_A t_B - 366k^2 - 291(t_A^2 + t_B^2))\end{aligned} \tag{2.19}$$

Inserting the initial equilibrium tax rate of the benchmark scenario [see eq. (2.9)], one gets

$$\pi_f - (\pi_1 + \pi_3) = -\frac{7}{128}a^2 + \frac{7}{64}ar + \frac{67}{128}ak - \frac{7}{128}r^2 - \frac{67}{128}rk - \frac{495}{512}k^2 \quad .$$

In contrast to the analysis above, there is the more intuitive result that higher trade costs may be profit enhancing for the international merged firm that can save on these costs: $d\left(\pi_f - (\pi_1 + \pi_3)\right)/dk > 0$. This holds if trade costs are not high enough such that these savings would already be shrinking in total due to a decreasing trade volume[51]. Moreover, it is now possible that such a merger is in the interest of the involved firms because the joint profits would rise if $k \in \left[\frac{14}{99}(a-r); \frac{2}{5}(a-r)\right]$[52]. Therefore, it is the endogenous response of national governments adjusting their optimal tax policies that renders these mergers unprofitable[53]. Above all, these privately profitable mergers would imply higher welfare levels[54] such that there might be an incentive that welfare maximizing governments would prefer to credibly stick to the tax rate that was optimal in the pre-merger situation. A relevant policy solution in the simple case of symmetric countries would be to establish a global welfare maximizing authority that is responsible for globally optimal tax policy. In the European context, the role of the European Commission and European Council might be strenghtened in order to overcome potential welfare losses due to an inefficiently low international consolidation of homogenous firms. Therefore this is one reason among many others calling for the establishment of a high degree of tax harmonization and global welfare maximizing subsidy schemes on the European or even higher international level.

Finally, one has to pinpoint that the presented analysis is limited with respect to several aspects. First, as already stated, the focus is on an intermediate level of trade costs $k \in \left[d; \frac{7}{20}(a-r)\right]$. If trade costs were lower, for example due to a high degree of market liberalization, a Nash equilibrium in pure strategies would not exist in the international merger scenario as there is always one country that will try to attract the production of the internationally mobile firm. If trade costs were instead higher, there would be no trade between countries. This would imply a duopolistic market structure in both countries to which both governments could intervene by choosing an optimal subsidy to generate a first best solution in the absence of foreign ownership.

[51] Precisely, $k < \frac{134}{495}(a-r)$ must be satisfied.

[52] Note that there is no minimium condition on trade costs in order to establish a Nash equilibrium in this scenario (compare condition 2.8). This is simply because governments cannot adjust their tax rates.

[53] Note that $k \in \left[\frac{14}{99}(a-r); \frac{2}{5}(a-r)\right]$ lies entirely in the analysed range of trade costs in the international merger scenario with optimal tax adjustment in the non-cooperative tax competition game.

[54] Inserting the welfare maximizing pre-merger tax rate (2.9) into the resulting welfare expression (2.7) of the post-merger market structure, privately profitable mergers are always socially desirable.

I have assumed to have national owned firms prior to the merger in order to focus on the role of trade costs here. Allowing for foreign ownership of national firms, as analysed in HS (2009), would of course vary the magnitude of the incentives on tax rates and its implication on profits and welfare. Nevertheless, the basic insights should be left unchanged as the fundamental effects are still at work. Especially, the higher tax elasticity to changes in trade costs in the post-merger situation is still in place even if there would be a complete ownership diversification prior to the merger either for all firms or only for the firms involved in the merger.
Another critical assumption constitutes the one of linear demand. Nevertheless, as long as the inverse demand is strictly monotonously decreasing with the quantity x, the fundamental incentives for optimal national tax policy should be at work again.
Moreover, I have focused on symmetric countries. Obviously, policy conclusions could become completely different if one considers asymmetric countries, especially from the national perspective. For example, there would be a *higher market share incentive* to subsidize domestic products for the foreign market if this market is relatively large.

Last but not least, one might think about the incentives of the non-merged firms. As I have assumed a symmetric setting, these firms have the same incentives to pursue a merger in the very beginning. Indeed, mergers occur often in waves such that a simultaneous international merger between all firms could be of interest. In this case a duopoly in each country would be created avoiding any (inefficient) trade. Moreover, these mergers would generate a complete international ownership diversification as all firms are now owned equally by both countries. This in turn would imply that national tax authorities have an increased incentive to tax profits accruing to foreigners. This overtaxation might counteract the efficiency gain of saved trade costs. But the question arises under which circumstances a double merger scenario might be realistic: essentially, all firms would have to coordinate such that they can pursue a simultaneous merger which is clearly against any anti-trust law. Consequently it might be reasonable to think about consecutive merging activities. This analysis is beyond the scope of this paper, but a consecutive merger of the remaining firms should also imply a trade-off between an increased incentive for governments to tax profits accruing to foreigners and a profit and welfare gain due to more home market production[55].

2.5 Conclusions

This paper has dealt with the interaction of non cooperative tax competition policy and cross border mergers in an oligopolistic market of a homogenous good under the consideration of trade costs. It has been shown that trade costs play a role in the determination of national welfare maximizing tax schemes. Thereby, the effect depends on the market structures under consideration. Finally, using a linear demand and symmetric countries, governments have always an incentive to levy higher tax rates as soon as there are higher trade costs. We have seen that this incentive is more pronounced if a cross border merger takes place. Considering the second instrument at the disposal of governments, namely merger control, governments should take the possibility to adjust their tax schemes into account if they have to decide on an international merger proposal in the very beginning. In the example of linear demand, we have seen that this tax response renders any cross-border merger unprofitable if firms do not benefit from further cost savings in addition to savings on trade costs. In the specific example considered here, governments should approve any proposed cross border mergers as the implied total cost savings are always sufficient to render the new market structure welfare increasing. The policy implication of this analysis is twofold: on the one hand, governments should adjust their tax rates in order to maximize national welfare for a new *given* market structure. On the other hand, market concentration by cross border merging activities introduces an incentive for higher taxes dependant on the level of trade costs which renders mergers unprofitable although they might be socially beneficial. This is the case if there are important savings on inefficient trade costs. Therefore governments might have an incentive for international tax coordination in order to overcome these welfare losses. They can even be better off by keeping taxes

[55] A complete analysis of alternative merger scenarios also comprises the alternative of national mergers. In comparison to an international merger, there would be again a trade off between a lower incentive for overtaxation in the national merger scenario and trade cost savings in the international merger.

or subsidies unchanged favoring cross-border merging activities[56]. But the best way to overcome negative welfare effects of inefficient trade costs is, of course, to diminish these trade costs as far as possible. The abolishment of any trade barriers, for example as proposed in the Doha Development Agenda might also trigger more efficient sector specific tax and subsidy schemes.The extent to which welfare implications change if countries are asymmetric might be up to future research.

[56] If countries are symmetric, maximizing global welfare would also be optimal from a national perspective.

Part II

R&D in Europe

- an overview of business R&D expenditure and its implications for growth accounting -

Chapter 3

Business R&D expenditure and capital in Europe[57]

3.1 Introduction

The economic literature has long recognized the importance of innovation and its organized production in the form of research and development (R&D) in fostering productivity (Arrow 1962; Griliches 1979; Romer 1990; Grossman and Helpman 1991; for an overview see Uppenberg 2009a). One specific feature of knowledge is that it has public-good characteristics: non-rivalness and non-exhaustibility. This means that knowledge, whose producers incur private costs, can "spill over" to other private entities (Arrow 1962). In the presence of spillovers, increasing returns to scale can be achieved in production, translating into long-run economic growth (Romer 1990).

Considering the eminent role attributed to R&D in promoting productivity growth, a country's total R&D expenditure is widely regarded as an informative measure of its technological innovation capacity and, hence as one of the determinants of its long-run growth. Moreover, there is evidence for own R&D being important for the absorption of new knowledge produced by others (Cohen and Levinthal 1989; Griffith et al. 2004). Thus a country's own R&D expenditure is also regarded as a measure of its ability to

[57] This chapter is joint work with Christian Helmers (University of Oxford) and Hubert Strauss (EIB Luxembourg).

benefit from international knowledge spillovers.

Conceptually, R&D is an input measure of innovation and does not necessarily reflect the actual amount of innovation produced. Indeed, producing an invention and turning it into a commercial success usually involves a considerable time lag and is subject to uncertainty. This means that the relation between R&D expenditure and resulting innovations – let alone productivity advances – is not easily identifiable. The economic literature has nevertheless extensively looked at the input side when assessing innovation activities of countries, industries and firms because finding good empirical measures of innovation is challenging. R&D expenditure is the most precise and best-researched innovation input measure available so far, albeit not the most comprehensive one[58].

When firms develop new products and processes, they do not only build on knowledge acquired in the current year but use a large stock of knowledge accumulated inside and outside the firm over many years through basic research, experimental development, prototypes, and learning from past failures. Hence, just as for tangible capital, it is the size of the R&D capital stock rather than the last vintage of R&D expenditure that determines output in a given year. The R&D capital stock may be interpreted as the value of the business sector's aggregate scientific and engineering knowledge.

The principal motivation for measuring the stock of R&D capital is to assess its widely-recognised contribution to GDP growth. Yet, knowing the R&D capital stocks requires treating R&D expenditure as an investment in the first place. The fundamental shift away from treating R&D as an intermediate input for firms towards treating it as an investment represents one of the major changes to the System of National Accounts agreed internationally in 2008 (European Commission et al. 2009, p. 206). The move has consequences for the estimated levels and growth rates of GDP, labour productivity and factor income shares[59].

This study gives a broad-brushed overview of R&D in Europe, the US and Japan,

[58] For broad estimates of intangible capital, which also include brands, novel designs, firm-specific human capital and efficiency-enhancing innovations of firms' organisational structures, and their role in productivity growth see van Ark et al. (2009). See also Bontempi and Mairesse (2008).

[59] See also chapter 4 of this work.

thereby zooming in on the business sector and focusing more on R&D capital stocks than on R&D expenditure. Acknowledging the conceptual and measurement problems surrounding the construction of R&D capital stocks, we present updated and new estimates of business R&D capital stocks for 22 countries at the industry[60] level.

We uncover substantial variation in R&D capital stocks even across relatively homogenous industrialized economies. Differences exceed by far those in tangible capital and labour. There is hardly any sign of convergence in R&D capital stocks, both within the EU and between the EU, the US and Japan (the so-called triad). Throughout the triad, R&D capital stocks are concentrated on three broad manufacturing industries: Chemicals and pharmaceuticals, Transport equipment, and ICT and other equipment. Furthermore, we examine to what extent differences in estimated R&D capital stocks help understand diverging productivity dynamics across countries and industries. Finally, we illustrate how countries and industries differ with respect to how they blend R&D capital and tangible capital in producing output.

The paper is structured as follows. Section 3.2 provides a brief overview of trends and broad patterns of R&D expenditure in Europe. Section 3.3 presents estimates of R&D capital stocks and discusses their evolution over time as well as industry patterns. Section 3.4 illustrates factor input ratios by relating R&D capital stocks to the stocks of total tangible capital and of specific types of tangible assets. Section 3.5 summarises the main findings and discusses some policy implications. Since the concepts presented in this article are quite technical, readers find a glossary of technical terms in appendix 3.1.

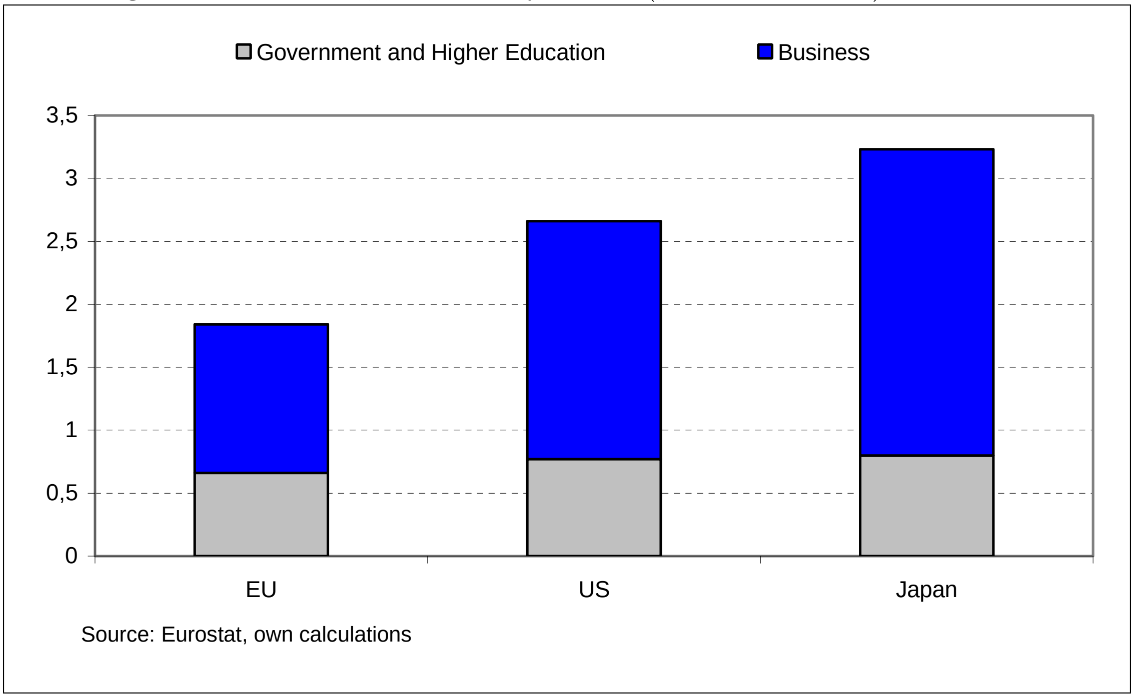
[60] In this paper, "industry" refers to the branches of the International Standard Industrial Classification (ISIC) or regional variants thereof (e.g. the NACE for Europe) and, hence, may refer to services as well as to manufacturing. By contrast, "sector" relates to institutional sectors of the national accounts such as households, non-financial corporations and the government.

3.2 Business R&D expenditure in Europe: Trends and patterns

3.2.1 Total and business R&D: Stable over time and below target

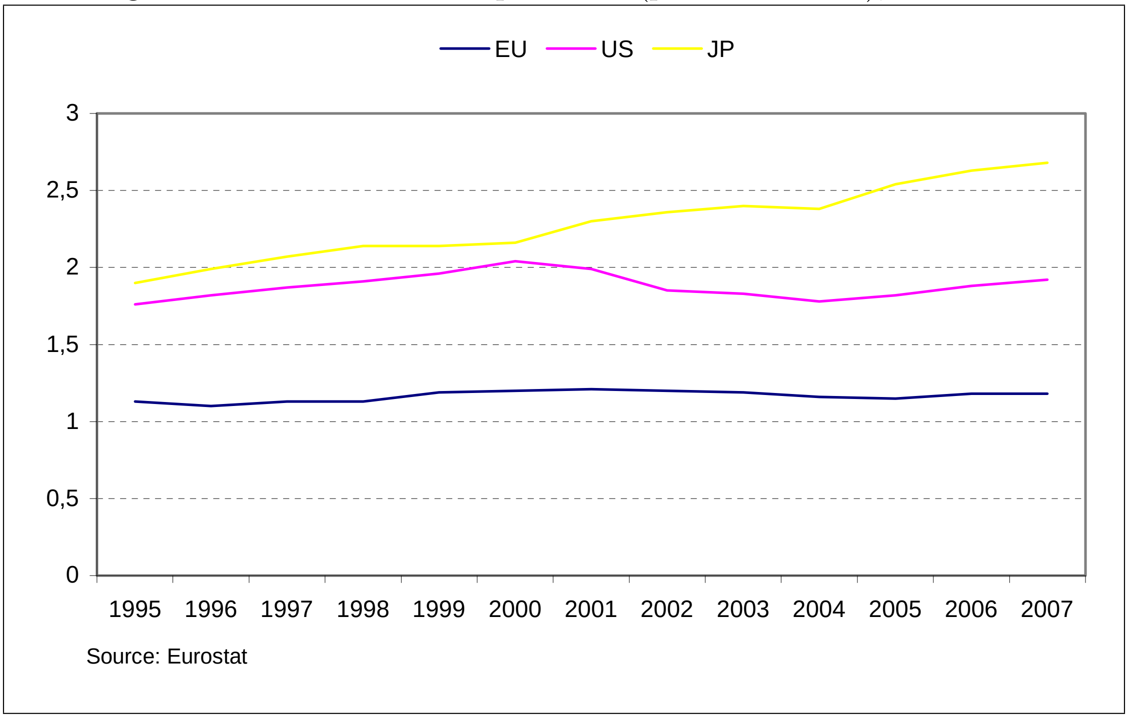
At the summit in Lisbon in 2000, EU heads of state launched an ambitious strategy for growth and jobs, which has since been known as the Lisbon strategy. The main objective is to close Europe's gap in productivity growth vis-à-vis the US and to make the EU economy the most productive and competitive economy in the world. To help governments reach this overarching goal, the strategy sets a number of quantifiable objectives in a wide range of policy fields relevant for GDP growth such as labour markets, product market competition, entrepreneurship, higher education, and research and innovation.

Figure 3.1: R&D expenditure by sector (percent of GDP), 2000-2007



One of the most visible Lisbon targets is that of increasing total R&D expenditure to 3 percent of GDP, with 2 percent of GDP coming from the business sector. It is also one of the targets that have been missed most markedly. Economy-wide, the EU has spent, on average, only 1.8 percent of GDP on R&D this decade, compared with 2.7 percent for the US and 3.2 percent for Japan (Figure 3.1). The breakdown of these figures by institutional sector indicates that the gap is in the business sector whereas R&D by governments and higher-education institutions is on par with the US and Japan. In 2007, Business expenditure on R&D (BERD) represented close to 1.2 percent of GDP. An increase by 70 percent would be required to meet the Lisbon objective of 2 percent of GDP. This is why the remainder of this article focuses on business R&D from subsection 3.2.2 onwards.

Figure 3.2: Business R&D expenditure (percent of GDP), 1995-2007



Not only was the EU missing the 3-percent target in the late 2000s but there is no sign that the Union has started moving towards the target over time. BERD in the EU has been stuck at about 1.2 percent of GDP for more than a decade and there is no catching up with the US and Japan (Figure 3.2). On the contrary, Japan is speeding ahead.

Among the EU member states, only Finland and Sweden have total R&D expenditure above 3 percent of GDP, followed by Austria, Denmark and Germany at around

2 $\frac{1}{2}$ percent (appendix 3.3). The apparent stagnation of R&D expenditure in the EU masks remarkable increases in some countries. For example, BERD has sharply increased in Austria and Denmark. Starting from a much lower level, Spain, Portugal and the Baltic countries have also recorded significant growth in BERD even though their total R&D expenditure is still at or below 1 percent of GDP.

3.2.2 The EU is less R&D intensive than the US and Japan also at the industry level

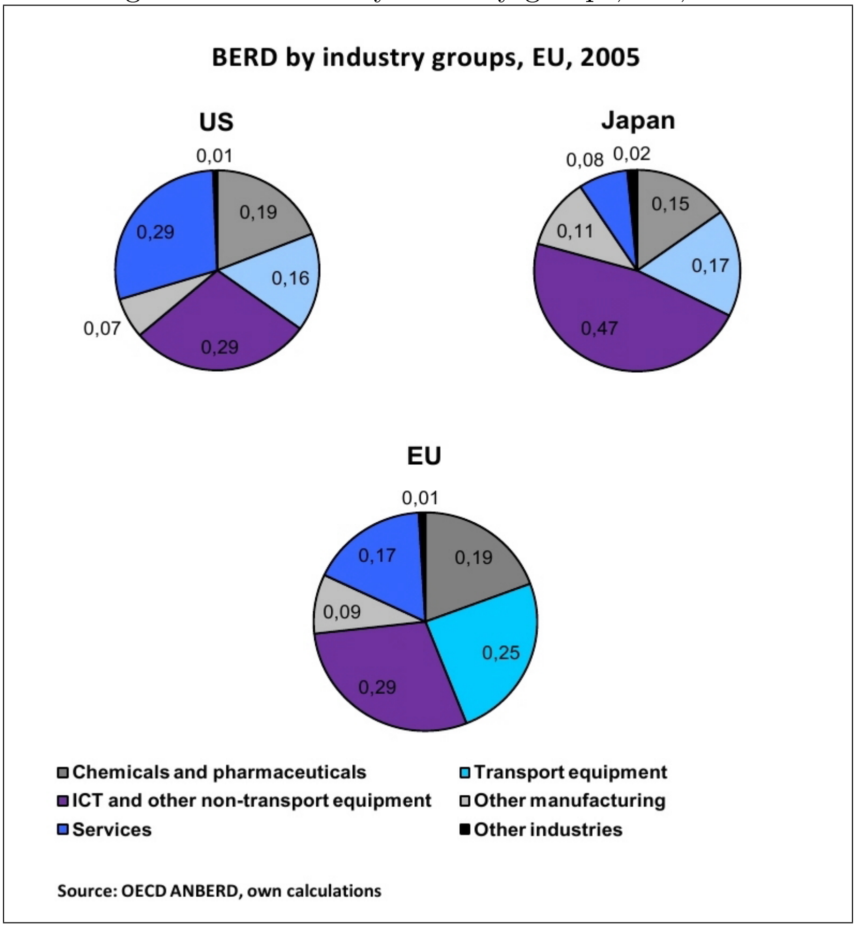
A natural question to ask in further diagnosing Europe's comparatively low BERD is whether it persists at the level of individual industries. Indeed, Europe's low overall BERD could reflect (*i*) low R&D intensity – defined as BERD relative to value added – in most or all industries (R&D intensity effect), (*ii*) an industry composition effect whereby Europe might be specialised on industries relying less on formalized R&D, or (*iii*) a combination of (*i*) and (*ii*)[61].

In answering this question, it is useful to start by showing which industries spend most on R&D. Figure 3.3 gives this information for the three economic zones of the triad. Three main insights emerge. First, three broad manufacturing-industry groups account for the brunt of R&D: Chemicals and pharmaceuticals (ISIC 24), Transport equipment (ISIC 34 and 35) and ICT and other non-transport equipment (ISIC 29 to 33). These industries make up three quarters of aggregate BERD in the EU and even 80 percent in Japan although they produce less than one-tenth of GDP[62]. Second, within these three leading industry groups, Japan's R&D is more concentrated on ICT equipment than R&D in the EU and the US while Europe has a stronger focus on Transport equipment. Third, outside the three leading manufacturing industry groups, the US records a significant share of BERD – almost one third – in services whereas Japan spends a lot on other manufacturing.

[61] This subsection draws on and updates Uppenberg (2009b).

[62] Because of their high R&D intensity, the individual industries in the three broad groups are all labelled as either high-technology or medium-to-high-technology in the OECD's classification of technology intensities in manufacturing while the remaining manufacturing industries are "low-technology" or "medium-to-low technology". See Table A1 of Danguy et al. (2009) for an overview of all individual manufacturing industries.

Figure 3.3: BERD by industry groups, EU, 2005



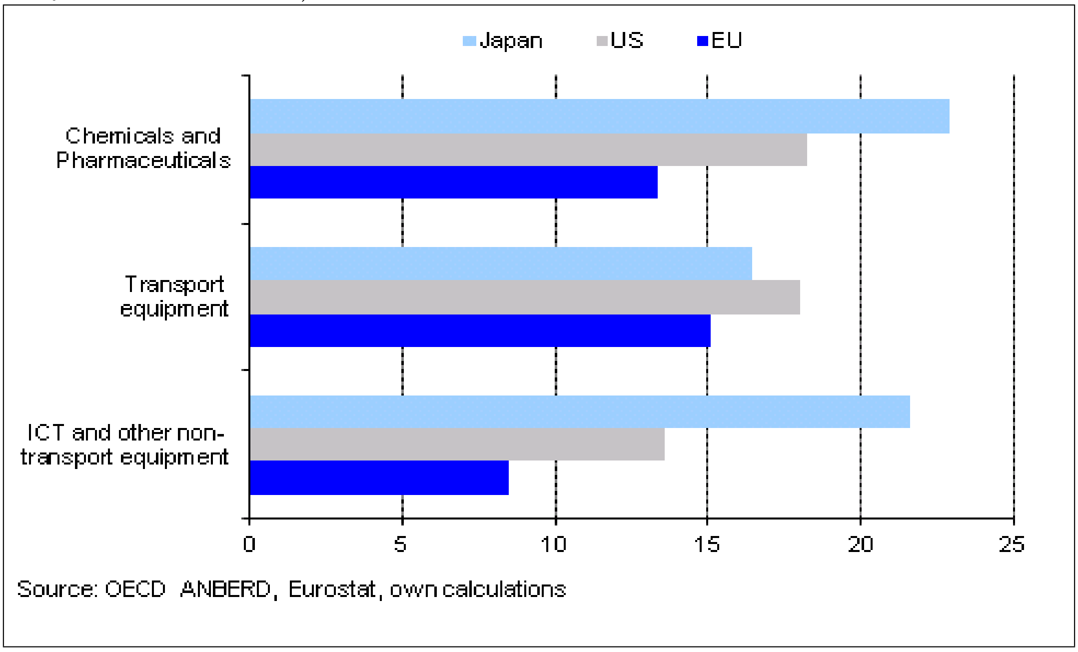
However, a strong caveat must be put on international comparisons of BERD at the industry level. According to international conventions, R&D statistics should allocate each R&D activity to the targeted product field (e.g. a new computer) rather than the main activity (measured by turnover) of the R&D-performing company. Moreover, R&D activities by specialised R&D service firms (ISIC 73) should be allocated to the industries purchasing these services. Countries differ as to whether they follow these conventions. This matters for the reported industry breakdown of BERD (see also appendix 3.2).

We therefore distinguish between three groups of countries by decreasing degree of comparability when comparing individual EU countries and their industry-level R&D data. Country group 1 comprises countries that follow the product field approach in collecting R&D data. These are Belgium, Finland, France, Sweden and the UK. We also include Germany and the Netherlands which, albeit following the main-activity approach, break down the R&D expenditure of their biggest R&D-performing companies by product field. The other countries collect BERD by companies' main activity. Country group 2 comprises countries that reallocate part or all of the BERD by R&D service firms to the consuming industries, most often located in manufacturing. All other countries are in country group 3. The bulk of BERD in the EU is done in group-1 countries whereas the US and Japan fall into group 3.

With that caveat in mind, we now look at industry-level R&D intensities and industry composition in order to understand what accounts for Europe's gap in overall BERD. In doing so, we focus on the three most R&D-intensive manufacturing industry groups that account for some three quarters of total BERD. Figure 3.4 shows that the lower overall R&D intensity in the EU compared with the US and Japan applies to all three industry groups. The chemical and pharmaceutical industry of Japan spent 23 percent of its value added on R&D in 2005, compared with 18 percent and 13 percent for their US and EU counterparts, respectively. Europe's gap is even larger in ICT and other non-transport equipment industries. By contrast, it is small in Transport equipment where R&D intensities are broadly the same throughout the triad at between 15 and 18 percent. The first conclusion therefore is that the R&D intensity effect is at work in key industries. Arguably, this accounts for a good part of Europe's gap in overall R&D expenditure vis-à-vis the US and Japan.

Nevertheless, this does not necessarily mean that lower R&D intensity accounts for all of the gap because differences in specialization might matter, too. This would be the case if the output of technology-intensive manufacturing industries were smaller in the EU compared with the US and Japan. Figure 3.5 shows the share of each industry group's value added in aggregate value added for the EU, the US and Japan. When measured at current prices – as is done in the left half of figure 3.5 – technology-intensive manufacturing contributed 8 percent to aggregate value added in the EU, more than in the US (6 percent) but less than in Japan (10 percent). Thus, it seems that the EU is more specialized in technology-intensive manufacturing production than the US and, hence, that the gap vis-à-vis the US is entirely due to lower industry R&D intensities.

Figure 3.4: R&D intensity in technology-intensive industries in the triad (percent of industry real value added), 2005

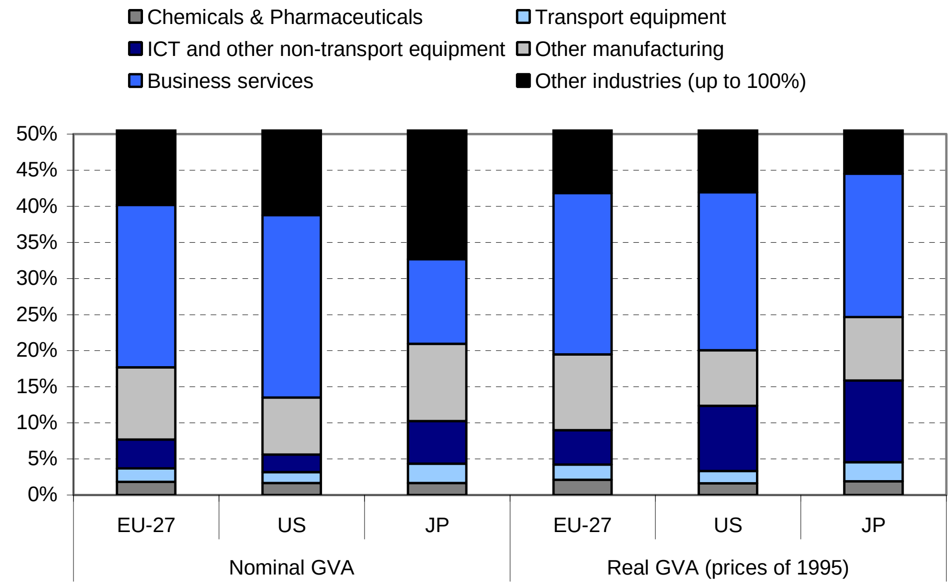


However, things look different when basing the analysis on real value added. The right half of figure 3.5 depicts each industry's contribution to real value added, i.e. value added in prices of 1995. From this perspective, the EU is less specialized than the US on technology-intensive manufacturing (share of 9 percent compared with $12\frac{1}{2}$ percent) while Japan continues to be most specialized (16 percent). The difference between real and nominal shares stems from ICT and other non-transport industries and is particularly pronounced in the US and Japan but small for the EU. This is because within this broad industry group, the US, and even more so Japan, are specialized on ICT-equipment production where prices decline much faster than in other industries such as machine-tools and optical instruments. Since these price declines are themselves to a large extent technology-driven and, hence, dependent on R&D, it makes sense to assess the industry's contribution to the level of GDP on real value added[63]. Closer inspection of the right half of figure 3.5 suggests that the share in real value added of ICT and other non-transport equipment is significantly smaller in the EU than in the US and in Japan, pointing to an industry composition effect alongside the R&D

[63] By contrast, nominal value added is more appropriate to assess the resource cost of R&D as compared to other inputs.

intensity effect mentioned above.

Figure 3.5: Industry composition of value added in the triad, 2005



Source: Eurostat, own calculations

Notes: In the right half of the figure, the share of each industry is defined as the ratio of the industry's real value added to total-economy real value added. The share of "All other industries" equals the difference between 100 percent and the sum of the five industry groups shown.

All in all, this section has shown that R&D expenditure in the EU lags behind that in the US and Japan, which is attributable to the business sector rather than the government sector. There has been no sign of the EU catching-up with the other areas of the triad over the past 15 years. BERD is heavily concentrated on three technology-intensive manufacturing industry groups: Transport equipment, ICT and other equipment, and Chemicals and Pharmaceuticals. The lower R&D intensities in the latter two and the modest size of Europe's ICT-producing industries account for most of the shortfall in overall BERD.

3.3 Business R&D capital stocks: New evidence at the country and industry levels

As stated in the introduction, deriving R&D capital stocks from annual investment flows allows to approximate a country's or an industry's scientific and engineering knowledge with a single number. It is a necessary step in using R&D in the analysis of economic growth[64]. This section first presents estimates of R&D capital stocks for the business sectors of 22 countries and illustrates how they have evolved over time. It then discusses how the stocks are distributed across industries and to what extent productivity is associated with R&D capital.

3.3.1 Estimates of aggregate business R&D capital stocks

In general terms, the capital stock K is a function of all past and current investment I and of depreciation. Specifically, the capital stock today equals the part of last year's capital stock that survives – that is, the part that has not depreciated – plus current investment – here the R&D expenditure of the current year. This is the intuition of the perpetual-inventory method, which can be written as:

$$K_t = K_{t-1}(1 - d) + I_t \tag{3.1}$$

where d denotes the depreciation rate and subscripts t and *(t-1)* stand for the current and previous year, respectively. The computation of R&D stocks is conceptually straightforward but it is fraught with practical challenges, notably with respect to the depreciation rate, the initial capital stock and the deflator. An overview of these issues and how they are addressed in this study is given in appendix 3.4.

[64] Ideally, the analysis should go one step further. As with capital services (OECD 2009a), the ideal input indicator for GDP accounting is R&D capital services. The use is complicated by varying estimates of returns to R&D. In using R&D capital stocks, we assume that they are proportional to R&D capital services, thereby abstracting from cyclical fluctuations and assuming a geometric depreciation pattern. See also figure A.4.1 (of the appendix to chapter 4) for an illustration of the differences between capital stocks and capital services.

This study covers all OECD countries with available data. In terms of cross-country comparability, the best data source for R&D expenditure at the industry level is the OECD's Analytical database on Business expenditure on R&D (ANBERD). This data source has also been used by the EU KLEMS project in the computation of R&D capital stocks up to 2003 (EU KLEMS 2008b). We use these R&D capital stocks and extend them to 2005 for some countries and to 2006 for others, thereby taking advantage of the most recent release of ANBERD (OECD 2009b). Moreover, we estimate R&D capital stocks for seven more countries: Austria, Greece, Hungary, Portugal, Slovakia, Slovenia and Turkey. In total, we get estimates for 22 countries: the US, Japan, Turkey as well as 19 EU countries. The latter cover about 95 percent of EU GDP and an even higher share of EU BERD, allowing for the calculation of EU aggregates. Further details about the data sources are given in appendix 3.5.

Figure 3.6: Business R&D capital stock estimates (percent of real value added), 2005

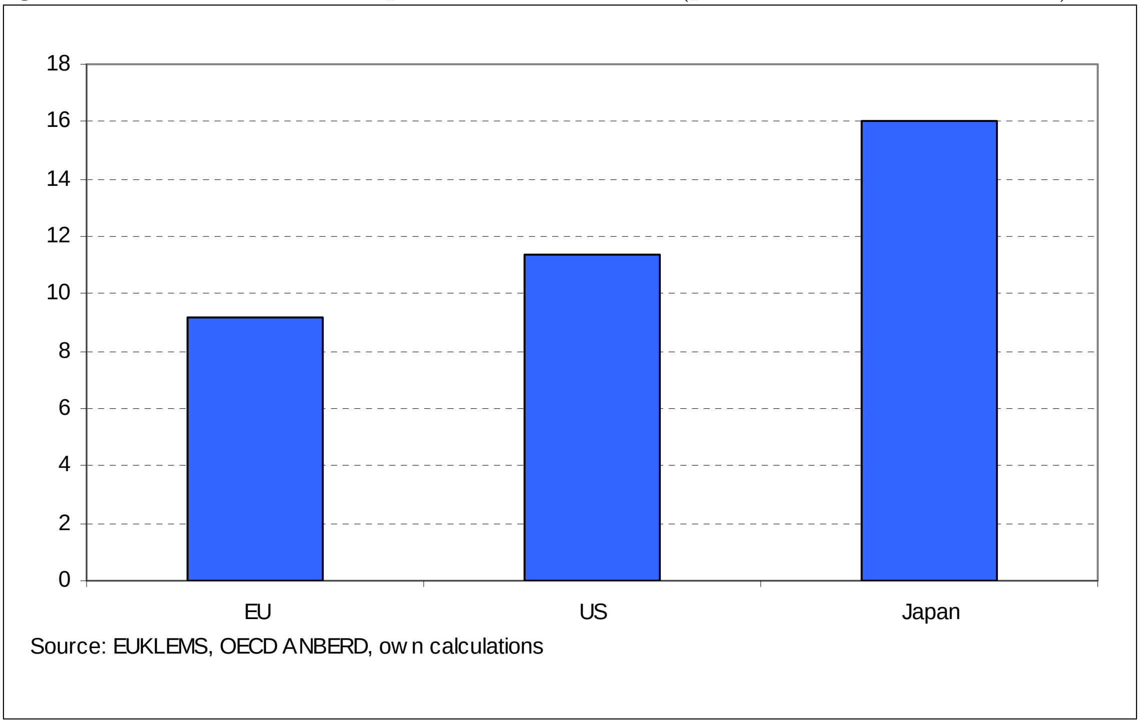
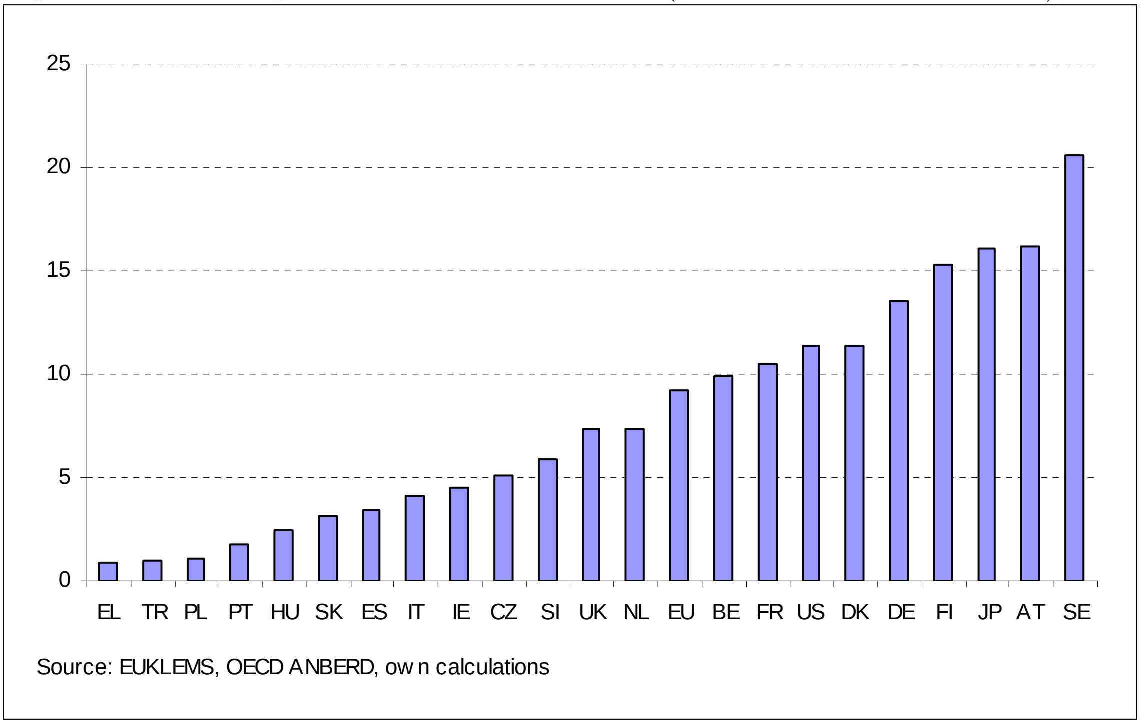


Figure 3.6 illustrates the results in their most aggregate way. The business R&D capital stock in the EU was equal to 9 percent of total real value added[65] in 2005

[65] In relating aggregate business R&D capital stocks to the size of the economy (i.e. output), we use aggregate real value added rather than real GDP in order to be consistent with the industry detail presented in figure 3.4 and in subsections 3.3.3, 3.3.4, 3.3.5 and 3.4.2. The two concepts are slightly

against $11\frac{1}{2}$ percent in the US and 16 percent in Japan. Put differently, production is more R&D capital intensive in the US than in the EU and is even more R&D capital intensive in Japan. Akin to R&D intensity in section 3.2, we refer to R&D capital intensity when expressing the R&D capital stock as a ratio of the size of the economy, notably of value added (also see appendix 3.1).

Figure 3.7: R&D capital stocks across countries (percent of real value added), 2005



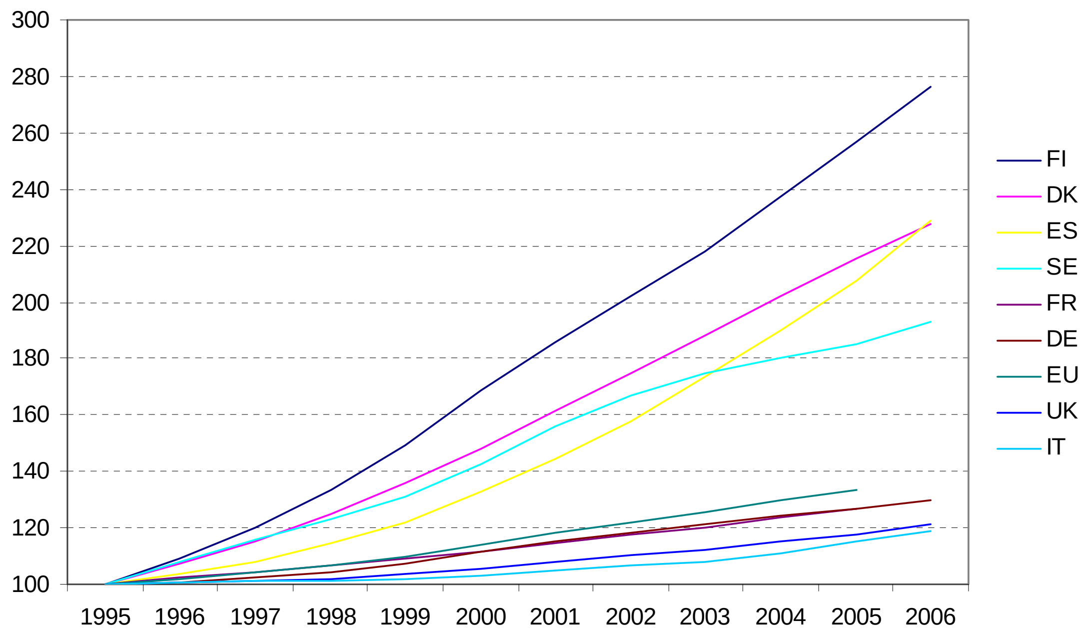
Europe's low R&D capital intensity masks dramatic cross-country differences, which are shown in figure 3.7. Overall, R&D capital is thinly spread throughout the southern and eastern parts of the EU. In 2005, the business R&D (BERD) capital stock represented 20 percent of value added in Sweden, around 15 percent in Finland and Austria but only 1 to 2 percent in Poland and Greece. A range from 1 to 20 is clearly in excess of the range of international differences in the use of other factors of production such as tangible capital and labour. As to the countries for which we present first estimates ever, business R&D capital stocks in 2005 were below the EU average in all of them ex-

different and, hence, the numbers of aggregate value added and GDP are not the same. For one thing, value added is evaluated at basic prices, GDP at market prices. What is more, the deflators used to obtain real measures are not the same for value added and GDP. As capital stocks are a real concept, we always divide them by real value added when discussing R&D capital intensities.

cept in Austria: 5.9 percent in Slovenia, 5.1 percent in the Czech Republic, 3.2 percent in Slovakia, 2.5 percent in Hungary, 1.8 percent in Portugal and 1 percent in Turkey. Another finding of our analysis is that more than 90 percent of the EU R&D capital stock is located in the western and northern EU countries.

3.3.2 Convergence and divergence of R&D capital stocks in the EU

Figure 3.8: R&D capital stocks of EU countries, 1995-2006



Source: EUKLEMS, OECD ANBERD, own calculation

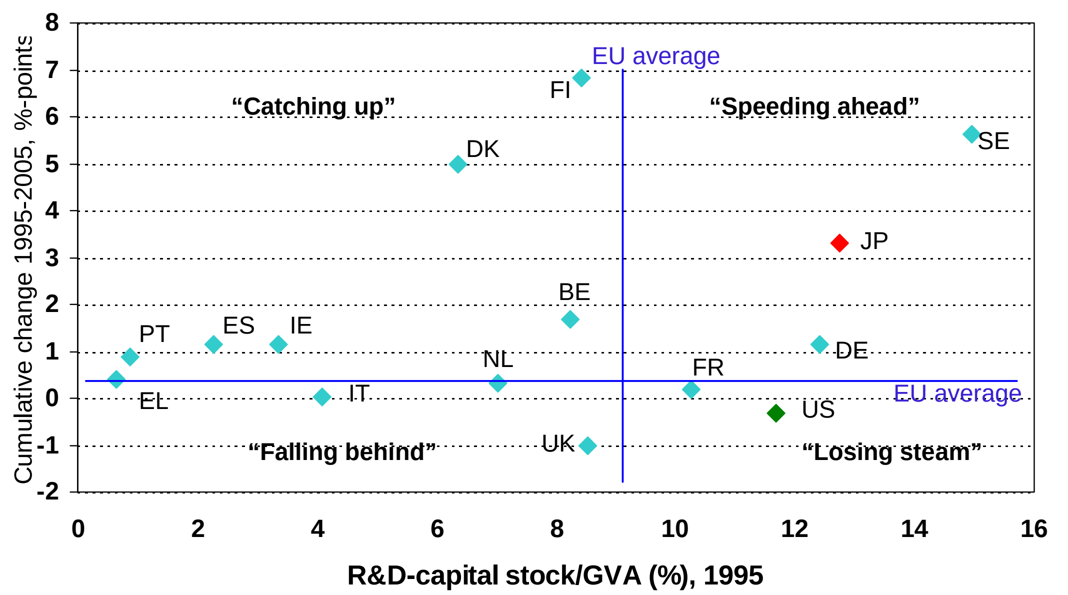
Notes: For each country, the R&D capital stock in 1995 is set equal to 100.
Evolutions in France and Germany have been very similar, making it difficult to distinguish the two lines.

To illustrate how rapidly persistent differences in the level of R&D expenditure translate into diverging R&D capital stocks, figure 3.8 sets each country's BERD capital stock equal to 100 in 1995, thus abstracting from its size relative to the economy or to other countries' stocks. For selected EU countries, the figure shows how the index evolves over time compared to each country's own starting position. Countries that swiftly increased their R&D expenditure saw their R&D capital stocks expand over the past decade, sometimes by 100 percent or more (Finland, Denmark, Spain and Sweden). However, R&D capital stocks have expanded only by 20 to 30 percent in the EU's largest economies, with the pace of expansion falling slightly short of the EU average in France and Germany and staying more significantly behind in Italy and the UK.

It takes a combination of the two views presented above – the size of the R&D capital stock relative to the economy and the evolution of R&D capital stocks over time – to make statements about whether EU countries tend to converge or diverge in terms of R&D capital intensity. This is done in figure 3.9, which depicts the R&D capital stock as a share of value added in 1995 on the horizontal axis and the change in that ratio during the subsequent decade on the vertical axis. The cross-lines represent the EU average for each dimension. They cut the figure into four areas. Countries in the upper-left area (e.g. Belgium) are catching up. they had below-average R&D capital stocks in 1995 but stocks have since grown faster than the EU average. Countries in the upper-right area are speeding ahead. A drastic example is Sweden. Already in 1995, it had Europe's largest R&D capital stock. Nevertheless, it recorded one of the strongest increases in that stock during the following decade. Below the horizontal line are countries with R&D capital stocks expanding more slowly than the EU average in the past decade, either because they are losing steam from a strong position (lower-right area) or because they are falling further behind the EU average (lower-left area). If all dots were aligned on a downward sloping line or at least situated in the upper-left and lower-right areas of the figure, all countries would be converging. Conversely, all dots being aligned on an upward-sloping line would signal divergence.

There has been hardly any convergence in R&D capital stocks between EU countries since 1995. True, six out of 13 EU countries are in the "catching-up" area while four are in the divergence zone with two speeding ahead (Germany and Sweden) and two falling behind (Italy and the UK). France, Greece and the Netherlands expanded their R&D capital stocks in line with the EU average and, hence, were neither converging nor diverging. Yet, a closer look at the countries in the "catching-up" area calls for a distinction between countries close to the average and those far behind. The close followers (Belgium, Denmark and Finland) overtook the EU average during 1995-2005

Figure 3.9: Convergence and divergence of R&D capital stocks at the country level



Source: EUKLEMS, OECD ANBERD, own calculations

Notes: The vertical line represents the R&D capital stock of the EU in 1995 (13 countries with available data) and the horizontal line the cumulative change of this stock. The intersection of the lines represents the data point for the EU.

and are now actually speeding ahead. In contrast, the true laggards' progress has been so slow that at the current pace it will take decades before they reach the EU average. Besides, the new EU member states are not shown in this picture due to missing data for 1995 but they further increase the number of countries far behind the EU average, for which convergence to the EU's average R&D capital intensity cannot be taken for granted and would, in any case, be a matter of decades, not years. Finally, the figure shows that the EU as a whole has fallen behind compared to Japan but has marginally caught up with the US.

As R&D capital is deemed to be an important (albeit so far unreported) factor of production in advanced economies, one would expect marked cross-country differences in the size of R&D capital stocks to shape countries' comparative advantage in technology-intensive manufacturing. This should especially be the case if higher R&D intensity of a given industry in one country is conducive to higher productivity of the industry compared with its counterpart in other countries. The connection between R&D capital and productivity will be shown in subsection 3.3.4 below.

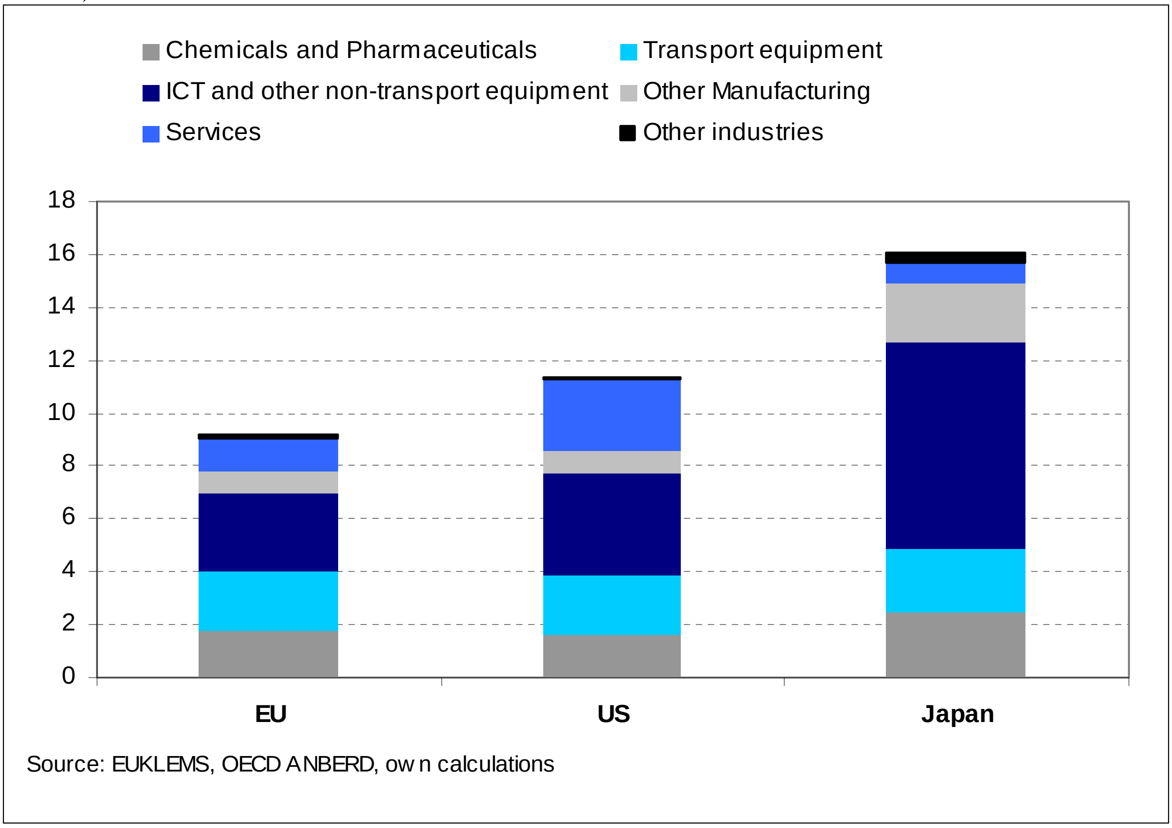
A comprehensive policy discussion on whether it is feasible and economically sensible to design policies that speed up convergence in national R&D capital stocks and whether governments in lagging EU countries are doing enough to that end is beyond the scope of this chapter. It suffices here to note that full convergence is unlikely to happen by itself because of the spillovers implied by knowledge-intensive activities and the resulting tendency for these activities to cluster in space. As a consequence, aiming at full convergence by all means would be very costly. Nevertheless, the economic literature on R&D stresses that R&D capital is not only needed in the most advanced economies to push the technology frontier further out. It is also required for lagging countries to catch up with the frontier since understanding and imitating new technological developments requires at least some domestic R&D activity (Griliches and Lichtenberg 1984; Griffith et al. 2003 and 2004; Cameron et al. 2005; Acemoglu et al. 2006). In line with these considerations, recent policy simulations find that countries with low R&D capital intensity would benefit the most from R&D promoting and skill-upgrading policies (D'Auria et al. 2009).

3.3.3 The distribution of R&D capital stocks across industries

This section has so far taken a bird's eye view on the R&D capital stocks. We now ask where in the economy the R&D capital stock is actually located, as it was done for R&D expenditure in subsection 3.2.2 above. We answer the question for the EU as a whole first before considering intra-EU differences.

Figure 3.10 depicts the estimated R&D capital stocks for the three zones of the triad and breaks the total down by large industry groups. There are two main insights, both broadly in line with figure 3.3 above. First, about three quarters of the total R&D capital stock are located in three industries: Chemicals and Pharmaceuticals, Transport equipment and ICT- and other equipment. Second, the comparison between the EU and each of Japan and the US suggests that only one industry group accounts for the differences in economy-wide R&D capital intensities. In particular, the difference between the EU and Japan is mainly due to Japan's high stock of R&D capital in ICT-producing industries. In turn, the difference between the EU and the US seems

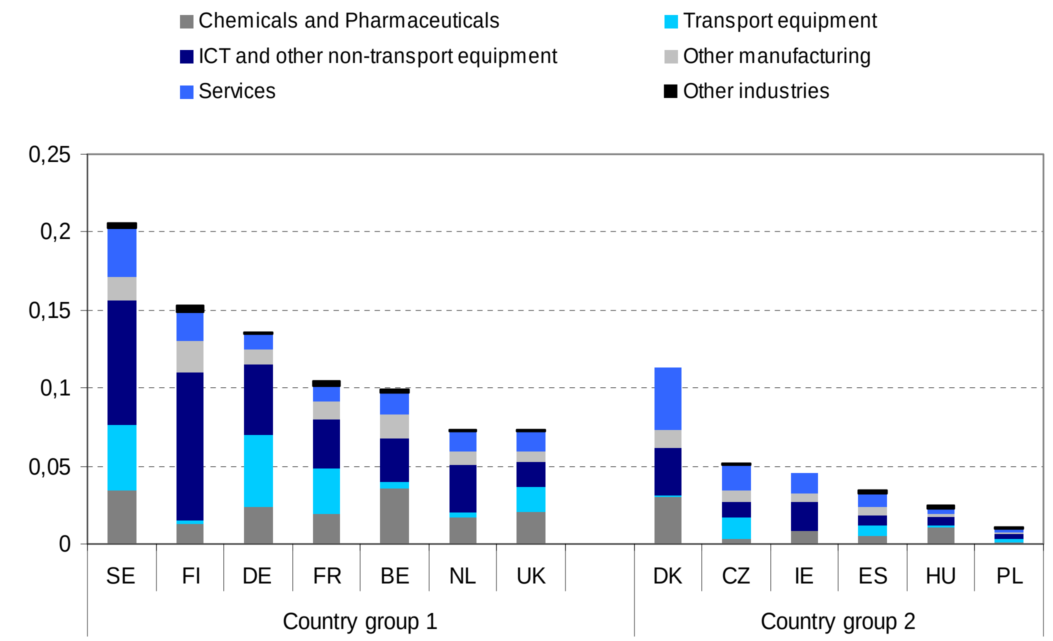
Figure 3.10: R&D capital stocks by industry in the triad (percent of total real value added), 2005



to be due to higher R&D capital stocks in the US services industries. This latter result, however, should be taken with a pinch of salt due to the comparability issues of industry-level R&D data discussed in subsection 3.2.2 above. Redistributing some of the US R&D capital stock from services to manufacturing would bring the industry breakdown in line with that in the EU. This suggests that the EU-US gap results from higher R&D capital intensity throughout the US economy.

Turning to intra-EU differences, countries differ not only with respect to the overall size of their R&D capital stocks but also with respect to the industry structure of these stocks. figure 3.11 depicts the ratio of the total R&D capital stock to real value added (height of the bars) like figure 3.7 above. In addition, it shows how much each industry group contributes to that ratio (height of the individual colour segments). Countries are sorted into two groups whereby data comparability is highest in country group 1 and lower in country group 2, as described in subsection 3.2.2 above. The other countries

Figure 3.11: R&D capital stocks by industry within the EU (percent of total real value added), 2005



Source: EUKLEMS, OECD ANBERD, own calculations
Notes:
- Country group 1 contains countries with high degree of international comparability of industry-level R&D data.
- Countries in country group 2 are less comparable but comparability is higher than for Group-3 countries, which are not shown.
- See subsection 3.2.2 and appendix 3.2 for details.

(group 3) are not shown since industry-level R&D data are hardly comparable with those of countries in groups 1 and 2.

The seven countries in country group 1 cover the lion's share of the R&D capital stock in the EU and are therefore fairly representative for the EU total in terms of industry structure. The frontrunners Sweden and Finland have huge R&D capital stocks in industries producing ICT and other non-transport equipment, both compared with R&D capital stocks in other industries and with the size of the overall economy. They also display larger R&D capital stocks in services. While R&D in Finland is concentrated on ICT equipment, Sweden has a more balanced industry composition of R&D capital. Sizeable R&D capital stocks in ICT-equipment industries are observed for France and Germany, too, but they are matched by R&D capital stocks in Transport equipment. In Belgium and the Netherlands, in turn, the chemical and pharmaceutical industry is the most important and second-most important host of R&D capital, respectively, alongside ICT and other non-transport equipment.

Denmark is the only R&D-capital-intensive EU country in group 2. Chemicals and Pharmaceuticals is the largest contributor in manufacturing. Services seem to be important, too, even though part of this might just be due to the main activity approach in R&D data collection. Finally, we find that the broad industry structure of R&D capital in Hungary resembles that of Belgium, with Chemicals and Pharmaceuticals being the main and ICT and other non-transport equipment the second contributor.

One should bear in mind that the industry contributions to aggregate R&D capital stocks shown in figures 3.10 and 3.11 might be affected by industry-composition effects: if a given industry is equally R&D capital intensive in two countries but is larger (relative to GDP) in country A than in country B, the industry contributes more to the total R&D capital stock in country A than its counterpart in country B.

3.3.4 R&D capital stocks and productivity

As R&D capital is arguably an important factor of production in advanced economies, the marked cross-country differences both in the size and the industry composition of R&D capital stocks could shape countries' comparative advantage in technology-intensive manufacturing. We now look at the association between productivity and R&D capital stocks to see whether the latter could be a source of dynamic comparative advantage.

Accounting for labour and tangible capital alone leaves a significant part of GDP growth unexplained (Solow 1956). The growth-accounting literature documents that the contribution to labour productivity growth of total factor productivity (TFP) is indeed large (see Uppenberg 2009a). TFP is a summary index of the overall efficiency with which capital and labour are combined in producing output and, hence TFP growth measures the gains in this efficiency. When TFP is estimated in a conventional growth-accounting framework featuring only labour and tangible capital, the resulting TFP levels are likely to be correlated with factors omitted from the accounting. R&D

capital stocks are one of these factors. For example, firms that obtain an innovative production process from investment in R&D enhance their productivity without a need to increase labour or tangible capital[66].

Figure 3.12 illustrates that there is indeed a positive link between R&D capital and conventional TFP at the industry level. It plots average annual TFP growth over the 15-year period 1991-2005 (vertical axis) against R&D capital intensity (horizontal axis) at the beginning of that period for 13 manufacturing industries and nine countries for which TFP data are available: Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, United Kingdom and the US. The scatter plot suggests a positive association between initial R&D capital intensity and subsequent TFP growth at the industry-level across countries[67]. But the graph also suggests considerable heterogeneity across countries and industries, both in terms of TFP growth and initial R&D capital intensity. A number of industries achieve rapid TFP growth while some others are characterised by a decline in TFP over the sample period[68]. R&D capital intensities are also strongly dispersed, with R&D capital stocks ranging from near zero to the equivalent of two years' value added[69]. Overall, TFP growth tends to be higher in more R&D capital intensive industries.

The positive correlation between R&D capital intensity and TFP growth comes as no surprise in light of a large body of theoretical endogenous-growth models attributing knowledge a key role in generating long-run growth. It has also been confirmed in the empirical literature assessing the link between R&D and TFP growth at the industry level. A classic reference is the study for the US by Griliches and Lichtenberg (1984) that examines the relation between privately funded R&D capital intensity and TFP for the manufacturing industry in the 1960s and 1970s. Notably, they find average

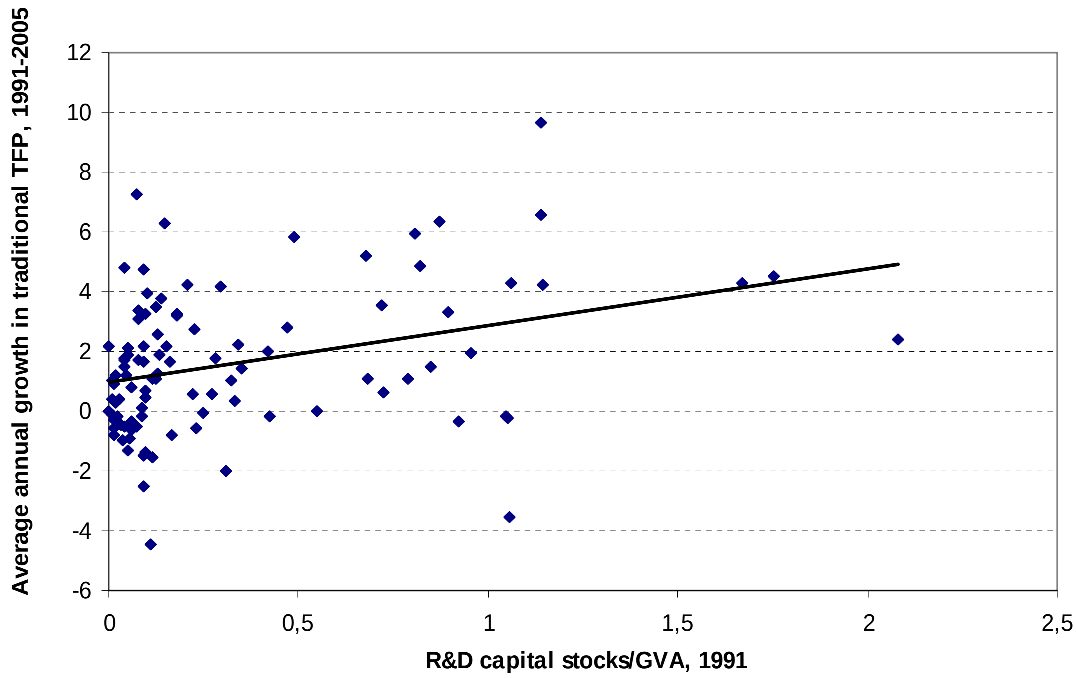
[66] The inclusion of R&D as additional production factor to capital and labour is treated in chapter 4 of this dissertation.

[67] The correlation coefficient is significant and amounts to 0.34, based on a country-industry sample cleaned for a few extreme outliers, i.e. country-industry pairs with average annual TFP growth rates larger than 20 percent or less than -5 percent.

[68] The industry with the sharpest drop in TFP Coke, refined petroleum and nuclear fuel" in Japan and the US. The fastest growing industries in the sample are ICT and other non-transport equipment in Japan, Wood and products of wood and cork in Finland and Chemicals and Pharmaceuticals in Germany.

[69] The lowest R&D capital intensities are in Wood and products of wood and cork and in Textiles and leather products in Italy. The highest R&D intensities are in Transport equipment, ICT and other equipment, in the Netherlands, the US, France, and the UK.

Figure 3.12: The connection between R&D capital stocks and productivity



Source: EUKLEMS, OECD ANBERD, own calculations

Notes: Each dot represents a country-industry pair from a sample of 13 manufacturing industries in nine countries with available data from 1991 to 2005. TFP data are taken from EUKLEMS' growth accounting results based on double-deflated value added and accounting for hours worked, labour quality and various types of tangible capital. R&D-capital intensity are industry-specific ratios of R&D capital stock (our estimates) to real value added (from EUKLEMS).

TFP growth to be higher in relatively more R&D-intensive industries[70].

3.3.5 Summing up

This section has presented new and updated estimates of business R&D capital stocks for 22 countries. The EU business R&D capital stock at 9 percent of GDP falls short of its US and Japanese counterparts, mostly due to much lower R&D capital intensity in industries producing ICT and other non-transport equipment. What is more, the R&D capital stock is geographically concentrated in the western and northern EU

[70] Guellec and van Pottelsberghe (2004) compute industry capital stocks differentiated by sources of their funding (private domestic, public and foreign) and compare their impacts on TFP. For a derivation of TFP measures in a growth regressions framework accounting also for R&D, see Eberhardt et al. (2010).

countries but scarce in southern EU countries and in the new member states. While all countries with above-average overall R&D capital stocks have substantial R&D capital in ICT and other non-transport equipment, some of them are R&D-intensive in Transport equipment or in Chemicals and Pharmaceuticals, too. These marked cross-country differences are expected to shape countries' comparative advantage in technology-intensive manufacturing.

This section has discussed R&D capital intensities, that is, the ratio of R&D capital to output in an industry or in the economy at large. Further insights are gained by relating R&D capital stocks to the stocks of tangible capital, i.e. to other inputs. This is done next.

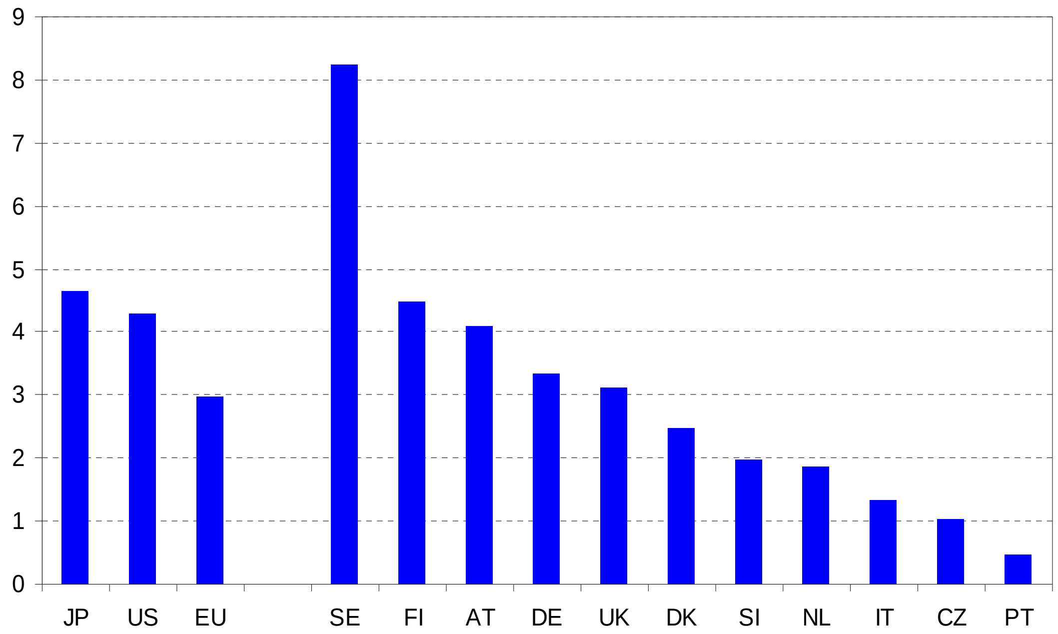
3.4 R&D capital and tangible capital

We now change the perspective and analyze the R&D capital ratio, which we define as the ratio of the R&D capital stock to the stock of tangible capital. By tangible capital, we refer to all asset types for which gross fixed capital formation is reported in the national accounts. It includes transport vehicles, ICT equipment, other machinery and equipment, residential constructions and non-residential structures, and some assets that are, strictly speaking, intangible such as software and expenditure on mineral exploration. R&D capital ratios are presented both for total tangible capital and for selected asset types. Again, we first look at countries as a whole and then take an industry perspective.

3.4.1 Economy-wide R&D capital ratios

Figure 3.13 shows that the EU business R&D capital stock is equal to 3 percent of its total stock of tangible capital. The EU has the lowest R&D capital ratio within the triad. This is as expected given the gap in R&D capital discussed above. More surprisingly, however, the US R&D capital ratio is virtually at par with Japan's $4\frac{1}{2}$ percent. This is because Japan's considerably higher R&D capital stock (relative to value added) is matched by a higher stock of tangible capital. Indeed, in 2005, Japan's aggregate output was produced with a tangible capital stock roughly $3\frac{1}{2}$ times the size of GDP, compared with $2\frac{1}{2}$ times GDP in the US.

Figure 3.13: R&D capital ratios (percent of total tangible capital), 2005



Source: EUKLEMS, OECD ANBERD, own calculations

Notes: Total tangible capital refers to all asset types for which gross fixed capital information is reported in the national accounts.

Again, there are considerable cross-country differences within the EU, too. The range of R&D capital ratios spans from 0.5 percent in Portugal to 8.2 percent in Sweden and, hence, broadly matches that of R&D capital intensities. Nevertheless, there are notable differences in the ranking of countries from the one shown in figure 3.7 above. For instance, the UK is now a close neighbour to Germany, which spends considerably more on R&D but also on tangible capital. In addition to the ranking, some of the cross-country differences in the size of the R&D capital ratios are surprisingly large, others surprisingly small. Take the two European R&D frontrunners, Sweden and Finland, for example. Sweden has almost twice the R&D capital ratio of Finland because it uses less tangible capital in production. All in all, the connection between total business R&D capital stocks and total tangible capital appears to be rather loose.

Breaking down total tangible capital into several asset classes and looking at specific R&D capital ratios (i.e. R&D capital ratios with respect to each asset class) delivers further evidence that a given stock of R&D capital might be associated with any stock of tangible assets. To see this, we divide the R&D capital stock by the aggregate stocks of certain types of tangible assets. We consider the following three asset types[71]: ICT and software, other machinery and equipment and non-residential structures[72]. It is important to note the change in perspective. This is not about R&D in the industries producing certain capital goods (as in Section 3.3) but about the economy-wide stock of a certain type of tangible asset such as ICT and software.

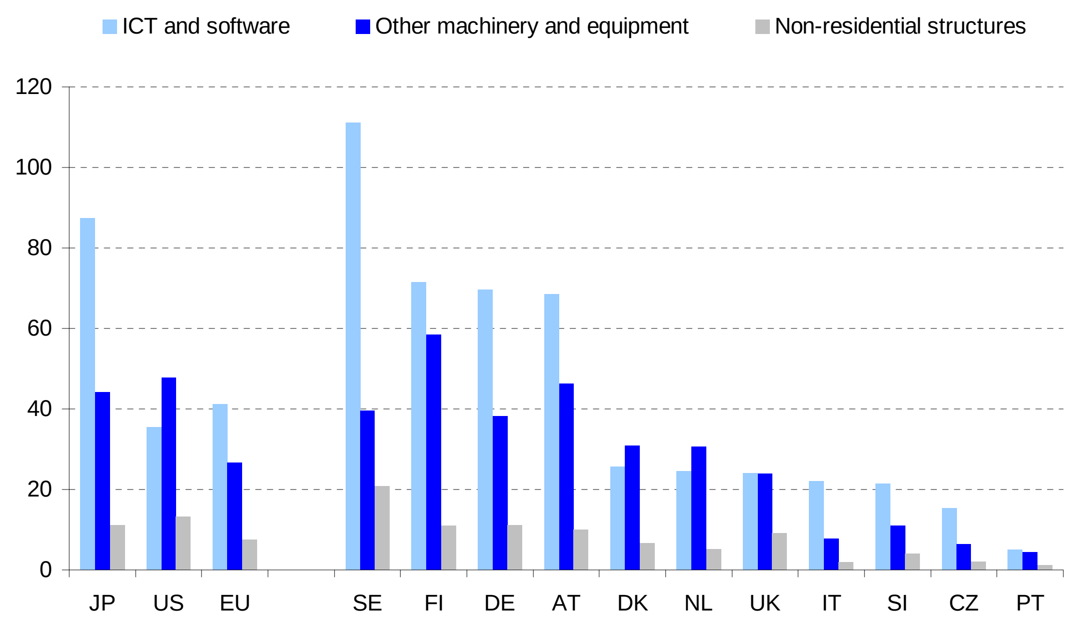
Figure 3.14 depicts the R&D capital ratio with respect to these three asset types. The following insights emerge. First, the EU business R&D capital stock is equal to 40 percent of its aggregate stock of ICT and software, about one quarter of its stock of other machinery and equipment and some 8 percent of its stock of non-residential structures. Second, there are deviations from the familiar R&D ranking "Japan first, US second and Europe third". On the one hand, the US economy uses ICT so intensively that the US R&D capital ratio with respect to ICT and software is less than half that of Japan and even lower than that of the EU. On the other hand, the US stocks of other machinery and equipment and of non-residential structures are so small relative to the US economy that the US R&D capital ratios with respect to each of these two asset types are higher than their counterparts in Japan despite Japan's considerably higher R&D capital intensity.

Third, also within the EU, the pattern of specific R&D capital ratios differs from what is expected given the distribution of R&D capital stocks alone. As far as the R&D capital ratio with respect to ICT and software is concerned, Germany is at par with the more R&D-capital-intensive countries Finland and Austria, suggesting that production in Germany is less ICT-intensive. Moreover, we find an unlikely similarity

[71] EU KLEMS distinguishes the following asset types: information technology, communication technology, software, transport vehicles, other machinery and equipment, residential constructions and non-residential structures. We lump the first three into one block, "ICT and software". We exclude residential constructions, which are not part of the productive capital stock. We also omit the stock of transport vehicles.

[72] Non-residential structures include buildings (e.g. warehouses, industrial and commercial buildings, hotels, restaurants, educational and health buildings) and other structures (e.g. highways and roads, railways, airfield runways, tunnels, waterways, harbours, long-distance pipelines and cables).

Figure 3.14: R&D capital ratios with respect to specific types of tangible capital (percent), 2005



Source: EUKLEMS, OECD ANBERD, own calculations

Notes: The bars represent the ratio of the R&D capital stock to the stock of each type of tangible assets at the country level.

in R&D capital ratios between the UK on the one hand and Denmark and Italy on the other, which in comparison to the UK points to higher ICT intensity in Denmark but lower ICT intensity in Italy.

Turning to the R&D capital ratio with respect to other machinery and equipment, the first interesting comparison is once more between Sweden and Finland. The ratio is lower in Sweden, suggesting that Sweden's higher R&D capital intensity is more than reversed by its much larger stock of other machinery and equipment: the latter was equal to half of total value added in 2005, compared with one quarter in Finland. As a consequence, it is Sweden's comparatively low stocks of non-residential structures and ICT and Software that account for its higher overall R&D capital ratio shown above in figure 3.13. A second comparison is among countries with lower R&D capital ratios. The ratios are equal for Denmark and the Netherlands as Denmark's larger R&D capital stock is matched by a larger stock of machinery and equipment. By contrast, Slovenia's ratio of 11 percent is half that of the UK reflecting Slovenia's strong manufacturing base and its correspondingly larger stock of machinery.

Finally, there are marked cross-country differences in the R&D capital ratio with respect to non-residential structures, for example between Sweden on the one hand and Finland, Austria and Germany on the other. Sweden's relatively lower stock of non-residential structures results in a higher bar in figure 3.14. In a similar vein, the stock of non-residential structures relative to the economy is also lower in the UK than in both the Netherlands and Slovenia. All in all, the discussion of economy-wide R&D capital ratios suggests that the cross-country differences with respect to the stocks of various types of tangible assets are not systematically aligned with those in R&D capital stocks.

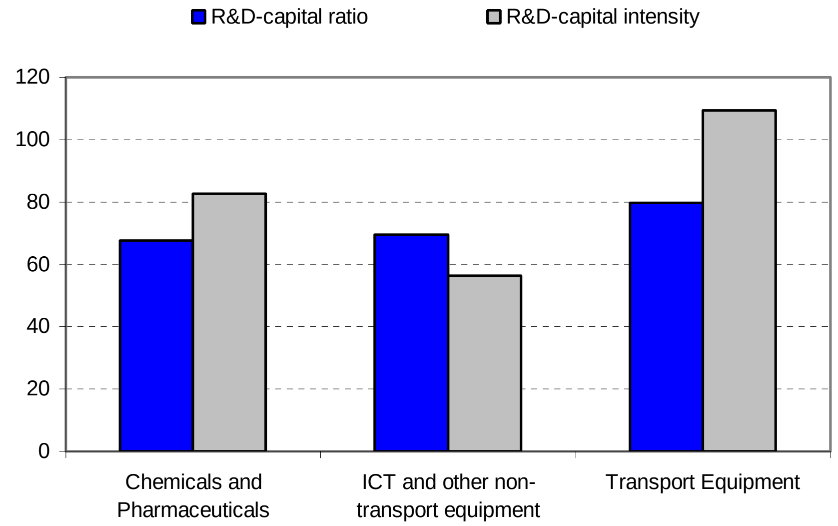
3.4.2 Industry-specific R&D capital ratios

We conclude this section by illustrating R&D capital ratios with respect to total tangible capital[73] in the EU for selected groups of industries. In addition, we show how these ratios compare with the pattern of R&D capital intensities. This is done in figures 3.15 and 3.16. figure 3.15 presents the results for technology-intensive manufacturing industries and figure 3.16 those for other industry groups. Figure 3.16 also recaps Europe's economy-wide R&D capital intensity and R&D capital ratio, illustrating that the latter is equal to about one third of the former at the aggregate level.

The following facts are worth noting from figures 3.15 and 3.16. First, technology-intensive manufacturing is characterized by higher R&D intensity (by a multiple of about 10) and higher R&D capital ratios (multiple of about 30) than the economy as a whole. Among the three industry groups, Transport equipment is the most R&D capital intensive with an R&D capital stock of 110 percent of value added in 2005, followed by Chemicals and Pharmaceuticals (80 percent) and ICT and other equipment (close to 60 percent). By contrast, the R&D capital ratios are about the same in all three industry groups. This means that the same hierarchy applies for R&D capital intensities as

[73] The even finer analysis of industry-specific R&D capital ratios with respect to specific assets is not presented in this chapter. We find that across countries and industries, R&D capital stocks are slightly correlated with the stocks of ICT and software but only in the sub-sample of high-tech manufacturing industries. No such correlation is found between R&D capital and tangible capital other than ICT. Results are available from the authors upon request.

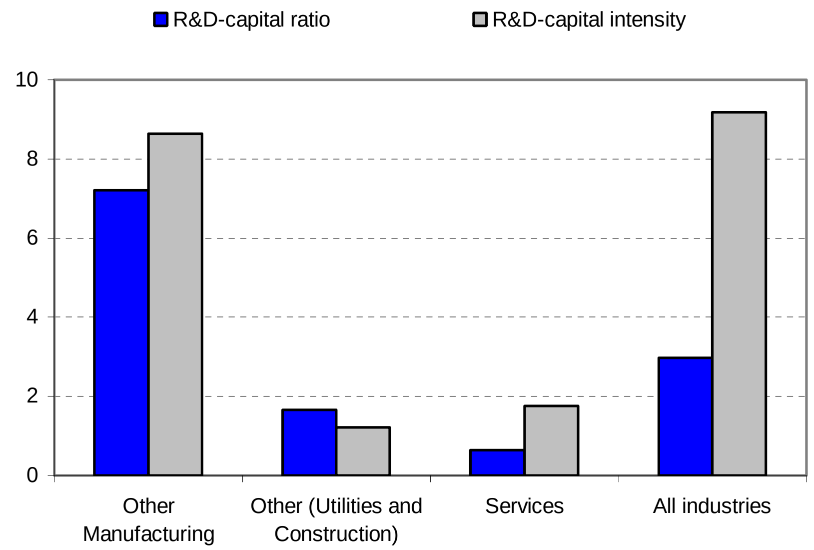
Figure 3.15: R&D capital intensities and R&D capital ratios: Technology-intensive manufacturing industries, EU, 2005



Source: EUKLEMS, OECD ANBERD, own calculations

Notes: The left bar represents the ratio of the R&D capital stock to the total stock of tangible capital in each industry. The right bar represents the ratio of the R&D capital stock to real value added in each industry.

Figure 3.16: R&D capital intensities and R&D capital ratios: Other industries, EU, 2005



Source: EUKLEMS, OECD ANBERD, own calculations

Notes: The left bar represents the ratio of the R&D capital stock to the total stock of tangible capital in each industry. The right bar represents the ratio of the R&D capital stock to real value added in each industry.

for tangible-capital intensities, with Transport equipment having the largest tangible capital stock relative to value added, Chemicals and Pharmaceuticals the second-largest etc.

Second, other manufacturing is still considerably more R&D intensive than other parts of the economy such as services. A final – albeit indirect – insight from the shown figures is that the tangible capital stock in all manufacturing industry groups by and large corresponds to about one year of value added whereas it is three years of value added in services.

All in all, the comparison of R&D capital ratios in this section has highlighted marked differences across countries and industries in how R&D capital and (specific types of) tangible capital are blended together in producing goods and services in the economy. As a consequence, the ranking of countries in terms of R&D capital ratios differs from that in terms of R&D capital intensities. For the R&D capital ratio with respect to particular asset types, we discover notable deviations from the familiar pattern "Japan first, US second, EU last".

3.5 Conclusions

R&D capital stocks are an important economic variable. Since it is the R&D capital stock rather than annual investment flows that matters for growth, this article has set out to compute R&D capital stocks for all industrialized countries with available data and has discussed how these stocks are linked to the flows that contribute to them.

Section 3.2 has shown that R&D expenditure in the EU lags behind that in the US and Japan, which is attributable to the business sector rather than the government sector. EU business R&D expenditure did not start increasing to get closer to that in the other countries of the triad over the past 15 years. Business R&D is heavily concentrated on three technology-intensive manufacturing industry groups: Chemicals and Pharmaceuticals, Transport equipment and ICT and other equipment. It is lower R&D intensity in the latter two as well as the small size of Europe's ICT producing industries that account for most of the shortfall in overall business R&D expenditure.

New estimates of business R&D capital stocks for 22 countries have been presented in Section 3.3. They show that the EU business R&D capital stock at 9 percent of GDP falls short of its US and Japanese counterparts, mostly due to much lower R&D capital intensity in ICT and other non-transport equipment-producing industries. The section has also highlighted the strong geographical concentration, especially the scarcity of R&D capital in the southern periphery and in the new member states of the EU. Using our R&D capital stock estimates, we have found a positive correlation, across industries and countries, between the initial stock of R&D capital in the early 1990s and the growth in TFP in the subsequent decade.

Section 3.4 has put R&D capital stocks in relation to tangible capital (R&D capital ratio), thus providing insights that cannot be gained from looking at R&D capital intensities alone. It has revealed pronounced differences in the way R&D capital and tangible capital are combined in production across the triad but also within the EU. Put differently, variations in the intensity of tangible-capital use are not strongly aligned with variations in R&D capital intensity.

As far as Europe's gap vis-à-vis the US and Japan in business R&D is concerned, the estimates in this study suggest that there is so much inertia in these capital stocks that reaching the Lisbon target of 2 percent of GDP spent each year on business R&D (and 3 percent economy-wide) is just a necessary but by no means sufficient step to close the EU-US gap in R&D capital any time soon. To allow for convergence in R&D capital stocks within the triad, significant increases in R&D expenditure need not only to happen but to be sustained for a long period of time.

Finally, our discussion of the geographic concentration within the EU has also shown that there is hardly any sign of convergence in business R&D capital stocks. A sharp geographical division of labour into R&D-intensive and less R&D-intensive areas might be efficient given the spillovers implied by knowledge-intensive activities and the resulting tendency for these activities to cluster in space. However, countries with very low R&D capital stocks need to ensure that they have sufficient technological absorption capacity to avoid getting disconnected from growth in productivity and living standards in the most advanced economies.

Chapter 4

R&D as investment in growth accounting - with an application to Germany and Slovenia

4.1 Introduction

During the last decades, knowledge has become an essential and valuable asset in the production process especially of developed countries. For this reason, they are often referred to as "knowledge economies". The main characteristic of a knowledge economy is its relatively high reliance on intellectual resources, as know-how and expertise, in comparison to physical inputs or natural resources. Therefore, there is a large literature highlighting the importance of knowledge for productivity, output and growth. For an overview, see e.g. Powell and Snellman (2004).

National account data, in contrast, often do not consider intellectual resources analogously to physical resources. Nordhaus claims, after his analysis of the history of lighting, that official national account data "miss the most important technological revolutions in history" (Nordhaus, 1997). This raises the question, if we should treat expenditures on knowledge, as for example on Research and Development (R&D) in the same way as expenditures on physical capital, as for example on machineries. So far, the latter is treated as investment, whereas the first one is not (see System of National

Accounts 1993 issued by the European Commission et al., 1993). Indeed, following Corrado, Hulten and Sichel (2005, p.13), we need a wider definition of capital in order to finish this unequal treatment ensuring that "any outlay intended to increase future rather than current consumption is capital investment". From a theoretical point of view, this seems very plausible because the treatment of expenditures as investment should depend on some fundamental characteristics and these should not include physical status. Evidently, there are a lot of practical problems if such a wide definition of capital investment was implemented rigorously. For example, training expenditures are likely to be an investment in firm specific resources, which in turn increase future output capacities. The problem is that such expenditures are rather difficult to measure accurately. For an overview and classification of intangible capital that might be treated (partly) as investment, see Corrado, Hulten and Sichel (2005).

This chapter will stick to business sector R&D expenditures[74] where most of them are not treated as investment in the currently implemented version of the System of National Accounts (SNA). Nevertheless, R&D is regularly carried out in order to generate future rather than current output. This point is taken up by the 2008 revision of the SNA recommending to treat R&D as investment in national accounts (see European Commission et al. 2009, p.206). Concerning the European Union, this new treatment will be implemented in 2014[75].

This chapter will illustrate the implications of the new treatment of R&D for national accounts and its consequent effects on growth accounting by giving a snapshot on the results for some R&D intensive industries. Therefore, I will exploit data on non-scientific business R&D of Slovenia and Germany where Helmers, Schulte and Strauss (2009) have calculated (respectively updated) new estimates on the existing R&D capital stocks. Before presenting this application, I will focus on the theoretical background and discuss its crucial assumptions, for example on depreciation and on the calculation of the rate of return. We will see that an appropriate treatment of R&D as investment leads to a higher level of gross value added (GVA) and potentially also to

[74]Business R&D excludes most notably scientific R&D conducted by universities and governmental agencies.

[75]Until now, satellite accounts for R&D only exist in some countries, e.g. in the U.S..

different growth rates of GVA. Essentially, if the growth of R&D is more dynamic than overall growth of GVA, the latter will be affected positively. With respect to growth accounting, the inclusion of R&D as an investment generates an additional production factor. This usually leads to a decrease of total factor productivity (TFP) as the residual in growth accounting. Finally, this chapter will give an outlook on intended future research using these data, namely the comparison of the resulting TFP-residuals over industries and on a potential strategy to identify spillover effects of R&D. Until now, this could not be conducted mainly due to inconsistencies of the data.

Considering the related literature, this chapter builds on the already mentioned work of Corrado, Hulten and Sichel (2005, 2009) who formalize the inclusion of intangible capital in the well known growth accounting model of Solow (1957) and Jorgenson-Grilliches (1967). They apply their model to the United States. Recent studies use the Corrado-Hulten-Sichel-framework with respect to several (European) countries leading to estimates for intangible capital and its contribution to economic growth (e.g. Haskel, Marrano and Wallis (2009) for the UK, Fukao et al. (2009) for Japan and Hao, Manole and van Ark (2009) for several main European countries). A survey of several studies can be found in van Ark et al. (2009). Despite of some crucial assumptions and measurement problems, these studies provide a first evidence of the strong importance of previously neglected capital goods. Further, this chapter relates to previous work of Helmers, Schulte and Strauss (2009) who have constructed R&D capital stocks for further countries, amongst others for Slovenia. Thereby, this work uses the recently built EU KLEMS growth and productivity accounts which is a sophisticated data source for growth accounting in European countries (EU KLEMS 2008a, 2009). It also offers some linked data for a limited country group with patent as well as R&D data (EU KLEMS 2008b). Alternative data sources used for growth accounting are for example the Total Economy Growth Accounting Database of the Groningen Growth Development Centre (see Timmer et al. 2003) and the ifo growth accounting database with respect to Germany (see Roehn, Eicher and Strobel 2007). Finally, from a theoretical point of view, this chapter is also related to the literature on the return on R&D and its spillover effects. For an overview of private and social returns of R&D see for example Fraumeni and Okubo (2005), for potential treatments of spillovers in growth accounting see Barro (1999).

This chapter is structured as follows: section 4.2 introduces the general framework of growth accounting with R&D as investment and discusses some crucial assumptions, section 4.3 describes the data and section 4.4 presents some first results for Slovenia and Germany. Section 4.5 gives some general notes and further thoughts before the final section concludes.

4.2 Framework of growth accounting with R&D as investment

Before implementing R&D in a growth accounting framework, it will be clarified how the classification of R&D as investment affects the national accounting identity of GDP. This will be done in the first part of this section. The second part uses these results with respect to their implications for a classical growth accounting framework.

4.2.1 R&D in the national accounting identity

Following Corrado, Hulten and Sichel (2009), it can be easily shown that it makes a difference for the production as well as for the income side of the accounting identity if R&D is treated as an intermediate input or as an investment good. Let us consider an economy with three goods, R&D (N), investment (I) and consumption (C). Assuming first that R&D is directly used within the period as an intermediate input, we only have an accumulation equation for capital that is accumulated by traditional investments (I): the capital stock (K) equals the depreciated stock of the previous period plus current investment yielding $K_t = K_{t-1}(1-\delta_K) + I_t$ with δ_K as the geometric depreciation rate of capital. R&D (N) can be undertaken by the use of the capital stock (K) and labour (L) and all three (N, K, L) are input factors for investment (I) and consumption (C).

The production functions and corresponding flows in year t can be written as

$$
\begin{aligned}
N_t &= F(L_t^N, K_t^N, t) & P_t^N N_t &= P_t^L L_t^N + P_t^K K_t^N \\
I_t &= F(L_t^I, K_t^I, N_t^I, t) & P_t^I I_t &= P_t^L L_t^I + P_t^K K_t^I + P_t^N N_t^I \\
C_t &= F(L_t^C, K_t^C, N_t^C, t) & P_t^C C_t &= P_t^L L_t^C + P_t^K K_t^C + P_t^N N_t^C
\end{aligned}
\tag{4.1}
$$

with the conditions $L_t = L_t^N + L_t^I + L_t^C$, $K_t = K_t^N + K_t^I + K_t^C$, $N_t = N_t^I + N_t^C$ and P_t^i as the respective factor and output prices. The input factor t represents total factor productivity at time t.

Most importantly, assuming factor compensation according to their marginal productivity, R&D does not appear in the accounting identity of GVA if it is treated as an intermediate input:

$$
P_t^Y Y_t = P_t^C C_t + P_t^I I_t = P_t^L L_t + P_t^K K_t \tag{4.2}
$$

The value of output ($P_t^Y Y_t$) equals only the sum of consumption and investment or the factor compensations of capital and labour because R&D nets out on the aggregate.

Intuitively this treatment of R&D would make perfect sense if R&D has been conducted for an immediate use in the production of an unique product (that will never be replicated). But this is clearly not the usual reason why at least business R&D is performed. As already mentioned in the introduction, everything that is produced in order to increase future rather than current consumption theoretically qualifies as investment from the consumption side perspective. From the production side, the symmetry principle calls for a similar argument: everything that is produced in order to increase output in subsequent periods (in practice after one year) should be treated as investment.

There are, of course, some practical problems with respect to the treatment of R&D as investment. For example, the lack of visibility how much of previous assets in R&D still exists makes it difficult to establish an appropriate depreciation rate in an accumulation equation of R&D capital[76]. Another problem can be some lack of

[76]Further problems in the calculation of an appropriate depr. rate are discussed in subs. 4.2.4.

verifiability of R&D assets. But such problems also exist with respect to traditional tangible investment goods and do not justify omitted efforts to overcome them[77]. All in all, it is highly plausible to treat business R&D expenditures fully as investment because they are generally undertaken in order to earn higher profits in the medium and long term. Potentially associated problems should be manageable analogue to the ones of tangible capital investments.

A full capitalization of R&D undertaken by the public sector might be more problematic because, for example, research undertaken by universities is often conducted without the goal to yield any direct positive returns[78]. This chapter concentrates on the treatment of business R&D.

Treating business R&D (N) fully as an investment, the current R&D capital stock (R_t), generated by the accumulation equation $R_t = R_{t-1}(1 - \delta_R) + N_t$, has to be used in the production functions. Equations (4.1) become

$$\begin{aligned} N_t &= F(L_t^R, K_t^R, R_t^R, t) \qquad & P_t^N N_t = P_t^L L_t^N + P_t^K K_t^N + P_t^R R_t^N \\ I_t &= F(L_t^I, K_t^I, R_t^I, t) \qquad & P_t^I I_t = P_t^L L_t^I + P_t^K K_t^I + P_t^R R_t^I \\ C_t &= F(L_t^C, K_t^C, R_t^C, t) \qquad & P_t^C C_t = P_t^L L_t^C + P_t^K K_t^C + P_t^R R_t^C \end{aligned} \tag{4.3}$$

with the conditions $L_t = L_t^N + L_t^I + L_t^C$ (as above) and $K_t = K_t^R + K_t^I + K_t^C$ (as above), but $R_t = R_t^I + R_t^C + R_t^N$.

By assuming again factor compensation according to marginal productivity, the accounting identity changes from (4.2) to:

$$P_t^Y Y_t = P_t^C C_t + P_t^I I_t + P_t^N N_t = P_t^L L_t + P_t^K K_t + P_t^R R_t \tag{4.4}$$

We see that the accounting identity has changed on *both* sides: on the product side, R&D has been added as additional investment evaluated at its investment price P_t^N; on the income side, the R&D capital stock must be compensated by the flow of capital

[77] For a discussion of these issues, see again e.g. Corrado, Hulten and Sichel (2005).

[78] A further distinct feature of R&D assets, which applies to public R&D (but partly also to private R&D), are sizable spillover effects from its owner to other firms, industries or even economies. Therefore, the non-rival character of R&D, which will also be discussed in this chapter, has to be considered especially with respect to public R&D.

services $P_t^R R_t$ now. The factor prices P_t^K and P_t^R are called the user cost of (R&D) capital and can be interpreted as the "rental price" of one unit of capital.

Do we indeed become richer as soon as we treat R&D or another input factor as investment? From an accounting perspective clearly yes, as GVA unambiguously raises. Expenditures on R&D are now treated as an output that is still there at the end of the period (analogously to an investment in machinery) instead of treating R&D as an intermediate input. This implies an increase of GVA by $P_t^N N_t$. As a consequence of a higher value of output, national income must also rise equivalently by $P_t^N N_t$ in order to ensure the accounting identity to hold. How can this work in practice as loans and interests are paid regardless how R&D is defined by economists? Here, we have to notice that income accruing to capital is measured as a residual in national accounts, namely as gross value added (GVA) minus labour compensation. Knowing that GVA increases by $P_t^N N_t$, it must be a part of capital compensation that becomes larger because the sum of salaries does not change. These increasing parts are in practice retained earnings which were underestimated before. In the accounting identity, this increased capital compensation must be attributed to the compensation of K and R now[79]. Details on the adequate treatment of R&D in national accounts can be found in the appendix.

I turn now to the growth accounting framework which will be built on the accounting identity (4.4).

4.2.2 Growth accounting with intangible capital

Following the growth accounting framework introduced by Solow (1957) and Jorgenson - Griliches (1967), logarithmic differentiation is applied to the accounting identity (4.4) in order to calculate the growth contributions of the input factors (L, K, R) in the production function (4.3). Thereby two crucial assumptions are needed: constant returns to scale and factor compensation according to their marginal return on GVA.

[79] It will become clear in the next sections that the compensation of traditional tangible capital may also change by a classification of R&D as investment.

Then the sources of growth equation equals

$$\Delta \ln Y_t = s_t^L \Delta \ln L_t + s_t^K \Delta \ln K_t + s_t^R \Delta \ln R_t + \Delta \ln t \tag{4.5}$$

with Δ indicating the changes between periods t and $t-1$ and with s as revenue shares. $\Delta \ln t$ represents the contribution of TFP. The revenue shares s are defined in the following way as two-period averages:

$$\begin{aligned} s_t^L &= \frac{1}{2}\left(\frac{P_t^L L_t}{P_t^Y Y_t} + \frac{P_{t-1}^L L_{t-1}}{P_{t-1}^Y Y_{t-1}}\right) \\ s_t^K &= \frac{1}{2}\left(\frac{P_t^K K_t}{P_t^Y Y_t} + \frac{P_{t-1}^K K_{t-1}}{P_{t-1}^Y Y_{t-1}}\right) \\ s_t^R &= \frac{1}{2}\left(\frac{P_t^R R_t}{P_t^Y Y_t} + \frac{P_{t-1}^R R_{t-1}}{P_{t-1}^Y Y_{t-1}}\right) \end{aligned} \tag{4.6}$$

Due to the assumption of constant returns to scale it is ensured that these shares sum up to one. This specification has also been used in the EU KLEMS database on which this chapter will build in the next sections[80]. The analysis is conducted on the industry level whereby industry-subscripts are omitted for clarity purposes.

How can this procedure be implemented? As described in the next section, the primary source of data are national accounts which provide data on GVA on the industry level as well as on labour compensation ($P_t^L L_t$). The difference between these two must be equal to total capital compensation ($P_t^K K_t + P_t^R R_t$). Having data on the (R&D) capital stock and estimates on the user cost of the respective stock (P_t^K and P_t^R) allows us to split this sum into its different asset types. Thereby, also tangible capital K can be divided into several asset types, for example in IT and Non-IT assets. Here, it is reasonable to assume that investors are indifferent between two investment opportunities if they yield the same return such that the following arbitrage condition must hold by defining $P_{k,t}^U$ as user cost and $P_{k,t}^{Inv}$ as investment price of asset k at time t:

$$-P_{k,t}^{Inv} + P_{k,t+1}^U + (1-\delta_k)P_{k,t+1}^{Inv} = i_t P_{k,t}^{Inv} \tag{4.7}$$

[80] Cost shares are an alternative to revenue shares in growth accounting.

So, an investor is indifferent between an investment in asset k purchased at its investment price $P_{k,t}^{Inv}$ (P_t^I w.r.t. tangible capital investment and P_t^N w.r.t. R&D investment following the previous notation), lending this asset which generates revenues according to its user cost $P_{k,t+1}^U$ and selling the depreciated asset in the next period for $(1-\delta_k)P_{k,t+1}^{Inv}$ on the one hand and earning a nominal rate of return i by using the money for an alternative investment opportunity on the other hand. This must hold for every asset type k, either tangible capital or R&D capital. Solving (4.7) for $P_{k,t}^U$ gives the cost of capital equation as used by EU KLEMS:

$$P_{k,t}^U = P_{k,t-1}^{Inv} i_t + \delta_k P_{k,t}^{Inv} - (P_{k,t}^{Inv} - P_{k,t-1}^{Inv}) \tag{4.8}$$

Now, it must be clarified which nominal rate of return i is applied here. There are two competing procedures: either an appropriate exogenous value is assumed *ex-ante* or the rate of return is calculated endogenously *ex-post* as a residual. The first approach uses, for example, government bond rates. The latter, which is used in this chapter, ensures perfect consistency between income and production accounts[81]. Therefore i is calculated as a residual such that overall capital compensation for all assets (calculated as GVA minus labour compensation) is exhausted and the arbitrage condition (4.7) holds. Due to this procedure the ex-post calculated rate of return is also called *internal rate of return*. Following the EU KLEMS procedure (see EU KLEMS 2007, p.34) but integrating R&D as an asset type k and defining Cap as the sum of tangible capital K and R&D capital R, the nominal rate of return becomes

$$i_t = \frac{P_t^Y Y_t - P_t^L L_t + \sum_k (P_{k,t}^{Inv} - P_{k,t-1}^{Inv}) Cap_{k,t} - \sum_k P_{k,t}^{Inv} \delta_k Cap_{k,t}}{\sum_k P_{k,t-1}^{Inv} Cap_{k,t}} \tag{4.9}$$

with $P_t^Y Y_t - P_t^L L_t$ as the equivalent for total capital compensation. This rate of return must be the same for all assets but it is allowed to vary across industries (and countries) because the procedure presented in this section is applied separately on the industry level. Of course, one might argue that the arbitrage condition (4.7) should also hold across industries. But this would, of course, violate the consistency between

[81] For a discussion, see EU KLEMS (2008a) or Erumban (2008), table 1.

income and production accounts and contradict the general assumption in classical growth accounting that production factors are paid according to their social marginal productivity.

Finally, in order to aggregate several asset types into one measure of capital services, as for example $\Delta \ln K_t$ in (4.5), the different marginal products (as for example of investments in IT and machineries) must be considered by an appropriate weighting procedure which employs the corresponding user cost of capital calculated in (4.8). R&D capital might be integrated in this procedure as well or be treated separately in order to identify R_t in (4.5). The aggregation looks as follows:

$$\begin{aligned} \Delta \ln K_t &= \sum_k \overline{v}_{k,t} \Delta \ln K_{k,t} \quad \text{with } k \neq R\&D \\ \overline{v}_{k,t} &= \frac{1}{2}(v_{k,t} + v_{k,t-1}) \quad \text{and} \quad v_{k,t} = P^U_{k,t} K_{k,t} / (\sum_k P^U_{k,t} K_{k,t}) \end{aligned} \tag{4.10}$$

In the final parts of this section, I will discuss some crucial assumptions that are essential in the growth accounting framework and especially focus on the depreciation rate of (R&D) capital.

4.2.3 Discussion of some crucial assumptions

Differences between the *ex-ante* and *ex-post* rates of return have already been highlighted (see above). Another, very fundamental assumption in growth accounting is the marginalist principle saying that each factor is paid due to its marginal productivity on GVA. This implies that all factors are paid corresponding to their overall social return. Therefore it is implicitly assumed that social returns are identic to private returns. This would ensure that we are able to use the resulting factor compensation shares in competitive markets as a correct measure in (4.6). But social returns are often higher, notably with respect to R&D[82]. What happens in this case such that there is still consistency between income and production accounts? This depends on the character of the spillover: if a (R&D) capital asset of another firm becomes more

[82] For an overview of estimates of the private and social return of R&D, see e.g. Fraumeni (2005), table 8.1.

productive due to the spillover, then the enlarged GVA will also increase capital compensation, calculated as a residual $P_t^Y Y_t - P_t^L L_t$. This will lead ceteris paribus to a higher internal (ex-post calculated) rate of return such that the total value of services from the capital assets equals again total capital compensation [compare eq. (4.9)]. If, in contrast, the spillover effect leads to higher labour productivity triggering higher wages, then the difference between social and private return is already accounted for in the input factor labour. In general, growth accounting only considers the direct effect of an input factor on growth.

Moreover, also the assumption on constant returns to scale may be questioned due to the non-rival character of some R&D investments. Barro (1999) summarizes models with increasing returns and spillovers. He shows that growth contributions due to spillovers of a non-rival asset may enter in TFP if the usual factor income shares from the standard growth accounting framework are used.

This discussion is also related to the question if R&D, which is undertaken by governments without any private return (but potential social return), should be treated as investment in a growth accounting analysis that is based on marginalist principles. If there is indeed no direct return on such R&D, it is highly questionable if it qualifies as an investment at all in this framework (compare Sveikauskas 2007). This chapter, however, sticks to business R&D which is capitalized fully as already mentioned in the beginning of this section.

The practical implementation of this framework also implies assumptions on the depreciation rate and on the price deflators used. The results are very sensitive to both. I will have a close look on the depreciation rate in the following subsection[83].

4.2.4 Depreciation rates applied to the value and efficiency of existing capital

Which features should the depreciation rate fulfill ideally? First, it should be asset type specific, so varying due to the characteristics of the specific investment. Thereby it can

[83] An alternative to the output based GDP-deflator are e.g. labour cost based indices, more specialized output deflators or a combination of output and cost based deflators.

also take into account that some investments have a higher probability to fail than others: in doing so, a higher risk premium can be reflected by a (ceteris paribus) higher depreciation rate of the respective asset. Moreover, if we consider several industries, it is a priori reasonable to look for depreciation rates that vary across these industries because an investment may be faster outdated in one industry than in another. Unfortunately, such data on industry specific depreciation rates are not yet very reliable with respect to R&D. For an overview of studies of the varying estimates on R&D depreciation rates, see for example Mead (2007), tables 1 and 2. Building ranks for these studies by their reported depreciation rate in several main manufacturing industries shows that also the rank of one study varies widely across industries[84]. Therefore such estimates are apparently facing severe individual problems.

In contrast, depreciation rates should be constant across time (and also across countries if we consider several ones) in order to ensure comparability. Mainly for practical reasons, depreciation rates are assumed to be geometric ones (as commonly in growth accounting analysis)[85]. The advantage thereby is that this implies no distinction between different depreciation rates with respect to the value of the capital stock (yielding a so called age-price profile) and for the efficiency of the use of this stock as input factor (yielding a so called age-efficiency profile). The age-price and age-efficiency profile are just identic in this case such that we can also use capital stock data for the calculation of capital services as input factors in production[86].

Having presented the basic framework of growth accounting and having discussed some crucial assumptions, I turn now to the data that are used to show some basic results for growth accounting with R&D in Slovenia and Germany.

[84] Own calculations of the Persson correlation between the rank of two studies show that they are between $-0,54$ and $+0,58$ and only $+0,18$ in the mean.

[85] The use of geometric depreciation rates is also empirically supported and recommended by the OECD, see OECD (2009), chapter 12.

[86] The concepts of the age-price and age-efficiency profile and the underlying links to the differences between the capital stock on the one hand and the productive stock / capital services on the other hand are described in detail in the OECD manual *Measuring Capital*, OECD (2009). In brief, the capital stock measures the present wealth of the previous investments and the productive stock measures its efficiency as input factor in production. This is illustrated in figure A.4.1 of the appendix.

4.3 Data sources

In the following I will mainly use data of the EU KLEMS growth and productivity database (release November 2009) which offers data on GVA, various labour and tangible capital inputs as well as on the relevant deflators and depreciation rates. This database aims to cover the EU-25 area. Thereby it offers results of a growth accounting analysis using labour and capital but not R&D as input factors as outlined in the previous section (see EU KLEMS 2007). The main data source of EU KLEMS are national accounts. The recently built database has been constructed in order to ensure a high comparability between European countries by applying the same methodology and assumptions to all covered countries, for example on depreciation[87]. Depreciation rates are based on the industry by asset type depreciation rates from the U.S. bureau of economic analysis as described in Fraumeni (1997). Moreover, the database is quite detailed with respect to different asset types of capital (eight different types) but does not offer data on R&D investment and on the resulting R&D capital stocks in their main part. For some countries they are available in the EU KLEMS linked database (release 2008). Helmers, Schulte and Strauss (2009) have added and updated R&D capital stock data for further countries, amongst others for Slovenia. These R&D data are based on the OECD Analytical Business Enterprise Research and Development (ANBERD) database. A drawback of this as well as for alternative data sources that report R&D data on the industry level is that R&D is often completely assigned to the industry where the main activity of the considered company takes place. This is true for most European countries and implies that R&D expenditures undertaken my multiproduct companies end up completely in their field of main activity. This can seriously distort a correct assignment of R&D to industries on which growth accounting builds on[88]. Therefore this problem exists also for Slovenia and Germany where I will exemplarily look at some main manufacturing industries in the next section.

[87] This database has been constructed by the EU KLEMS consortium partners (e.g. the Groningen Growth and Development Centre) who have cooperated with national statistic offices. For details see EU KLEMS (2007).

[88] See also Helmers, Schulte and Strauss (2009), box 1 (or appendix 3.2 in this work) for a discussion of associated problems. R&D expenditure data by product field, in contrast, are scarce.

4.4 Some first results for Slovenia and Germany

I will concentrate on some main categories of manufacturing industries in Slovenia and Germany: Electrical and Optical Equipment Industries (ISIC 30t33), Rubber and Plastic Industries (ISIC 25), the broader category of not elsewhere classified Machineries (ISIC 29) and partly on Chemicals (ISIC 24)[89]. These are some examples of industries with a relatively high use of R&D where data are sufficiently available. I use Slovenia because I can analyse here R&D capital stock data of Helmers, Schulte and Strauss (2009) who are the first having constructed R&D capital stocks for Slovenia. Additionally I report results for Germany due to its higher reliability because of its size[90].

Before turning to the results, I will first concretise the main assumptions used in the implementation and point to problems occurred within this procedure.

4.4.1 Assumptions for implementation and occurring problems

I assume a 12% depreciation rate for R&D capital which is on the lower end of existing empirical estimates (compare again Mead 2007) but is in line with the one used in the EU KLEMS database on which this analysis builds on. Further, all different tangible capital data of EU KLEMS are used in the growth accounting analysis as outlined in subsection 4.2.2. Capital services are aggregated to ICT and non-ICT capital services analog to equation (4.10). ICT consists of the asset types computing equipment (IT), communication equipment (CT), and software (Soft) whereas non-ICT consists of other machinery and equipment (OMach), transport equipment (TraEq), (non-)residential structures (RStruc, OCon) and others (Others).

EU KLEMS growth accounting results could not be recalculated exactly using the

[89] Industry categories are used according to the International Standard Industrial Classification of all economic activities (ISIC).

[90] W.r.t. Germany, Helmers, Schulte and Strauss have only updated R&D capital stock data of EU KLEMS. EU KLEMS R&D capital stock data for Germany have already been used in a growth accounting analysis by van Ark et al. (2009). In contrast to this contribution, they don't focus on R&D as the only additional investment type but do a broadly based analysis of intangibles.

growth accounting framework outlined in this chapter (but without R&D capital as input factor) although this corresponds to their methodology. Thereby, even in country-industry pairs without any announced particularities in the data, some slight deviations remain in the basic calculations of the internal rate of return [compare eq. (4.9)] (but again without R&D) to the one delivered in their dataset[91]. Most likely, they perform a revaluation procedure of the existing capital stock in a different procedure than announced or there are some hidden data characteristics that could not be treated with. Further, it was impossible to come up with the same results of aggregate capital services analog to (4.10) even by using their reported rate of return[92] [93]. Final growth accounting analog to (4.5), in turn, would be perfectly replicable if their capital and labour services data were used. All in all, the following results, generated by an augmentation of the original EU KLEMS data by R&D as investment, must be taken having these problems in mind. Some first results using these data in the (growth) accounting framework are outlined in section 4.4.2.

4.4.2 Increase of GVA by reclassifying R&D as investment

Having noticed the data limitations in the previous subsection, there is nevertheless one undisputed result that holds by using these data: gross value added of the investigated industries increases in the amount of the investment costs $P_t^N N_t$ by classifying R&D as investment (see accounting identities (4.2) and (4.4)). Figure 4.1 shows that this increase is quite impressive with respect to the mentioned manufacturing industries.

As R&D is very dynamic, the inclusion of R&D as investment can also affect growth rates of GVA significantly, especially on the industry level where it is highly concentrated. For an example, the average growth rates for the chemical industry (ISIC 24) are shown in figure 4.2 (ISIC 24 had also the most prominent level effect on GVA in figure 4.1).

[91] For example, the average deviation in the Electrical and Optical Equipment Industry in Slovenia (Germany) is 7,6% (8,7%) *relatively* to the official EU KLEMS data.

[92] The average deviation of (non-)ICT capital services indices in the Electrical and Optical Equipment Industry of Slovenia and Germany are between 0,15% and 2,7%.

[93] Several tries have been done to overcome these problems, e.g. by using older releases of the data and different countries.

Figure 4.1: Increase of industry GVA by inclusion of R&D as investment

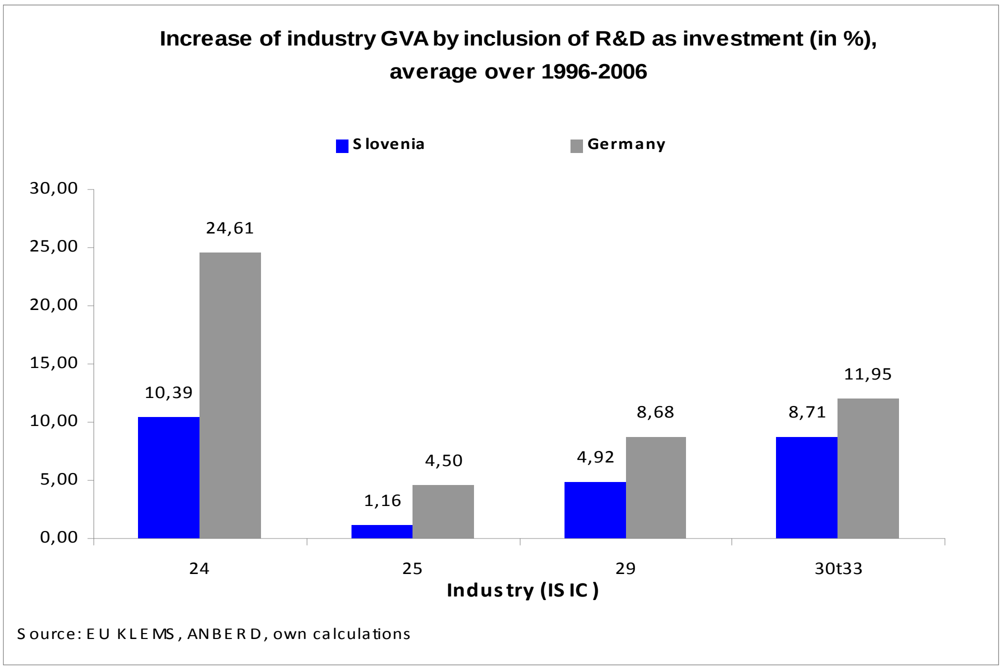


Figure 4.2 indicates that there must be an increasing path of investments in R&D, which is above average of overall growth of GVA, leading to higher growth rates in the scenario with R&D as investment. Nevertheless, a pinch of salt must be taken with respect to the results in the previous figures: as already mentioned, the assignment of R&D to industries following the "main activity" approach can be distortive on the industry level. Therefore such an analysis becomes more reliable (although potentially less informative) on higher aggregate levels[94].

[94] For further insights on the effects of GVA on the aggregate level see for example Fraumeni (2005).

Figure 4.2: Average yearly growth of industry GVA in chemical industries

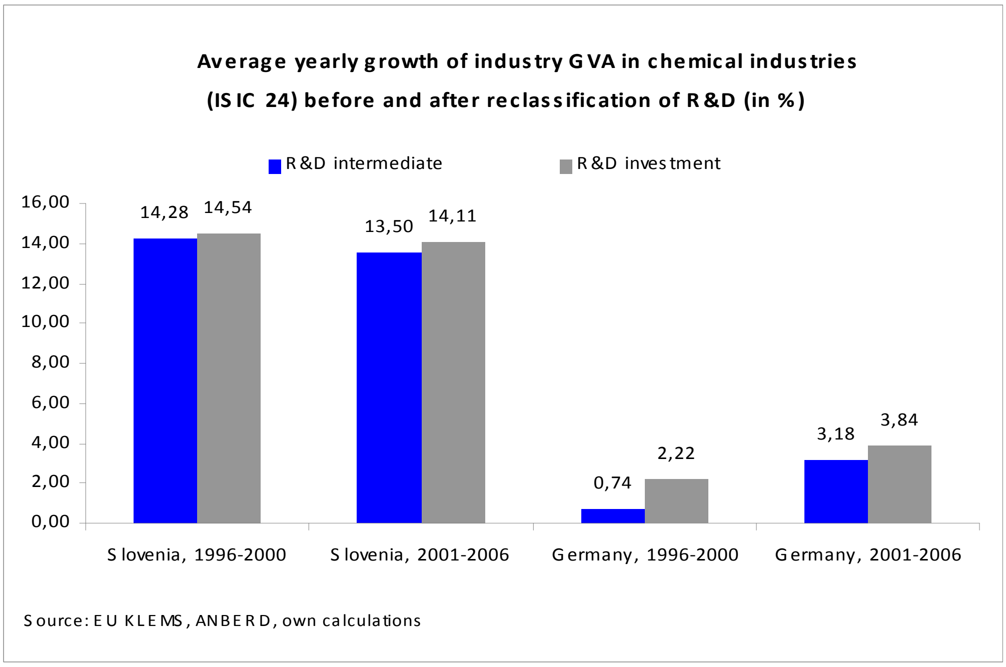


Table 4.1: Ex-post internal rate of return for some industries, 2006 (in %)

Country	R&D treated as	Industry 25	29	30t33
Slovenia	intermediate	10,53	10,00	9,94
	investment	*10,13*	*9,16*	*8,95*
Germany	intermediate	20,88	26,21	15,63
	investment	*17,05*	*38,19*	*8,85*

Source: Helmers et al. (2009), own calculations (based on EU KLEMS)

Note: ISIC 24 is not shown due to data problems with residential structures in Slovenia

4.4.3 Intermediate results in growth accounting

Coming to growth accounting with R&D, table 4.1 shows the results for the internal rate of return in (4.9) exemplarily for 2006 and compares it to the traditionally recalculated one without R&D as investment[95].

We see in this example that the rate has become smaller in most cases if R&D is taken as an investment. Therefore it was overestimated before if we believe that

[95] Note again that the traditionally recalculated internal rate of return is not identic to the one by EU KLEMS, see footnote 91.

R&D should appropriately be treated as investment. At first sigth, a declined internal rate of return is very plausible because we have included another asset type meaning that total capital compensation must be split up between more assets[96]. This would lead unambiguously to a lower internal rate of return if total capital compensation was unchanged. But this is not the case with respect to a reclassification of R&D as investment leading to higher GVA and higher total capital compensation. Therefore, it is impossible to say how the internal rate of return will develop in general[97]. Further, it must be noticed that the internal rate varies strongly across industries (and also across countries) in order to ensure consistency between income and production accounts. Such a flexibility might also be needed due to potential data insufficiencies with respect to a correct assignment of capital assets to industries (see discussion about the "main activity" assignment of R&D to industries above). Of course, a comparable nominal rate of return, e.g. government bonds, does not vary like this in reality. This indicates that results of growth accounting, especially on the industry level as done here, should not be overinterpreted.

The internal rate of return is calculated yearly and enters into the construction of the user cost of the different (R&D) asset types of capital in (4.8). Adding investment prices and depreciation rates (they do not change by a reclassification of R&D), tables A.4.1 and A.4.2 in the appendix report the final user cost of (R&D) capital in 2006. Due to their positive dependence on the internal rate of return, they simply change in the same direction as soon as R&D is reclassified.

User costs of all assets are in turn needed to construct capital services indices for R&D and for (non-)ICT assets according to (4.10). Results on logarithmic growth of capital services can be found in the appendix (tables A.4.3 and A.4.4).

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[96] Recall that the internal rate of return must ensure that total capital compensation is exhausted and that the arbitrage condition holds for all included assets.

[97] The changing internal rate of return is in contrast to the use of an ex-ante rate of return which is, by construction, invariant to different treatments of R&D.

Table 4.2: Growth contributions in Electrical and Optical Equipment (ISIC 30t33) with and without R&D as investment (in %), Slovenia 2001-2006

Asset	R&D treated as	2001	2002	2003	2004	2005	2006	Average 2001-2006
All (real GVA growth)	intermediate	8,81	8,24	3,67	7,25	4,42	9,19	6,93
	investment	*9,65*	*7,82*	*3,55*	*7,22*	*5,26*	*8,87*	*7,06*
R&D	intermediate	-	-	-	-	-	-	-
	investment	*0,87*	*0,65*	*0,64*	*0,64*	*0,55*	*0,47*	*0,64*
ICT	intermediate	1,41	0,05	0,23	0,14	0,18	0,02	0,34
	investment	*1,42*	*0,05*	*0,21*	*0,13*	*0,17*	*0,02*	*0,33*
Non-ICT	intermediate	2,05	1,88	1,88	1,56	1,48	1,20	1,67
	investment	*1,98*	*1,78*	*1,67*	*1,29*	*1,34*	*1,07*	*1,52*
Labour	intermediate	0,22	0,26	1,41	1,06	-0,55	-1,26	0,19
	investment	*0,20*	*0,24*	*1,30*	*0,98*	*-0,50*	*-1,15*	*0,18*
TFP	intermediate	5,13	6,05	0,15	4,49	3,31	9,23	4,73
	investment	*5,18*	*5,11*	*-0,26*	*4,19*	*3,71*	*8,46*	*4,40*

Source: own (re)calculations, based on EU KLEMS and Helmers et al. (2009)

Notes: The contribution of labour also contains changes in the composition of labour.

4.4.4 Final results in growth accounting

The sources of growth analysis of equation (4.5) can now be performed using the results on capital services indices underlying tables A.4.3 and A.4.4, using data on labour compensation $P_t^L L_t$ (available in the EU KLEMS database) and using compensation shares on (non-)ICT assets (also as estimated by EU KLEMS). Table 4.2 reports the results for Slovenia whereas the corresponding table for Germany can be found in the appendix (table A.4.5).

The table shows the resulting composition of industry GVA growth by (non-)ICT and R&D capital assets, labour and the residual total factor productivity (TFP) exemplarily for the Electrical and Optical Equipment Industry. Thereby, it compares these results to the ones based on the EU KLEMS database that treats R&D as an intermediate input (by using again the recalculated estimates in order to ensure consistency). For Slovenia I get, in the example of the Electrical and Optical Equipment Industry, the overall result that is in line with the usual expectation if a new intangible asset is added to growth accounting: the contribution of TFP shrinks by this inclusion[98].

[98] In 2001 and 2005, the absolute contribution of TFP has increased, but not its *relative* contribution

Moreover, also the contributions of the other factors, in this example especially of non-ICT assets, tend to be smaller[99]. This is not surprising because an overestimation is likely as long as a highly dynamic asset like R&D has been neglected. Finally, note that GVA *growth* is not always higher after considering R&D as an investment, although the *level* of GVA must have increased (see figure 4.1)[100]. The results for Germany are similar in their basic pattern. Interestingly, Germany's Electrical and Optical Equipment Industry shows more volatile growth rates in GVA although it is much bigger compared to Slovenia. Thereby, there are also several negative contributions to growth of the single assets[101]. In order to minimize such volatilites it is reasonable to focus on the last columns in tables 4.2 and A.4.3 where the average over 2001-2006 is reported. Here, the mentioned results become more obvious.

In general, disaggregated growth contributions may be driven by some specific characteristics and should not be overinterpreted. With respect to the Electrical and Optical Equipment Industry in Germany one might argue that the result can be easily distorted by some multiproduct companies whenever its diverse activities -as in the case of R&D- are assigned completely to its main activity. Nevertheless, this argument does not hold for large companies (like Siemens in this example) because Germany's statistic offices assign their activities to the correct industries if the company exceeds a certain size[102]. Finally note that average TFP in Slovenia is roughly the same as in Germany. Assuming that industry specific productivity is mainly dependant on some industry specific technology, this finding says that such a technology is available to the same extent in Slovenia as in Germany. Of course, this must not hold for other industries. Further investigations are needed here[103].

because also GVA has increased.

[99] Again, this would also hold if we were looking at their relative contributions to the respective GVA-growth.

[100] Note also that the lowered contribution of labour to industry GVA growth should not lead to the wrong conclusion that labour productivity has decreased. The opposite would be true because a higher output can be generated with the *same* labour input, see also the next section.

[101] This is possible for capital assets whenever depreciation is relatively high compared to new investments.

[102] For details on these different assignments according to the main activity or the product field approach, see appendix 3.2 in this work.

[103] The same calculations for industries ISIC 25 and ISIC 29 show at least similar TFP's in ISIC 25 of both countries.

4.4.5 Summary

Taking the example of the Electrical and Optical Equipment Industry in Slovenia, this section has illustrated that R&D taken as an investment rises the level of industry GVA and can trigger a higher growth rate. By doing growth accounting with these new data, the ex-post calculated nominal rate of return must be adjusted to ensure consistency between income and production accounts. This rate has lowered in the considered industries in Slovenia which also translates into new estimates for capital services. Finally, the inclusion of R&D as investment leads to a more realistic calculation of TFP which has been decreased here. Of course, the analysis is far from being complete and needs to be enlarged considerably. Then it might also be possible to analyse the pattern of TFP thoroughly. So far, we've seen that there are severe problems in the implementation of a growth accounting framework including R&D as an investment, for example with respect to an appropriate assignment of R&D to industries. This limits of course the explanatory power of these results and should also be taken as a warning not to overinterprete comparable results of other studies.

Amongst others, some further ideas about the behaviour of TFP will be outlined in the next section. Then the final section concludes.

4.5 General notes

It must be kept in mind that the framework of growth accounting is designed to look at the direct effects of the included assets on output and assumes factor compensation according to marginal productivity. So it is implicitly assumed in the presented framework that investments in R&D are completely non-public goods (compare section 4.2.3). But R&D is in fact partly non-rival such that growth accounting with R&D as investment still underestimates the importance of this asset for growth. In order to capture the overall effect of R&D on growth, alternative methods like econometric estimates should be considered. They lead of course to other drawbacks[104].

Nevertheless hints for spillover effects of R&D on the overall productivity can also

[104] For example, there are severe simultaneity problems in such estimates.

be detected using results from a growth accounting framework. Thereby it is possible to argue that a high R&D capital intensity (defined as R&D capital stocks over GVA) should have a positive impact on future productivity growth (measured by the growth of TFP) if there are (lagged) spillovers. A positive correlation between these two variables has been found in Helmers, Schulte and Strauss (2009, figure 12)[105] where TFP is taken from EU KLEMS and therefore calculated traditionally without R&D as investment. A problem there is that the initial R&D capital stock may also be positively correlated with future TFP values because R&D has been omitted as an investment asset in the underlying production function. An initial aim of this research project was to contribute to this discussion by calculating the corresponding TFP's in the same growth accounting framework but with R&D treated as an investment[106]. If there would still be a similar correlation between R&D capital intensity and future growth of TFP's, this might give a more accurate hint about existing spillovers of performed R&D leading to a higher overall productivity. Due to the mentioned problems in replication of the original EU KLEMS results, such a comparative analysis was not possible so far[107].

Finally it must be noticed that there are even more aspects that have not been considered in this chapter but are relevant for the outcome in growth accounting. Especially the inclusion of taxes may also affect TFP.

4.6 Conclusions

Summarizing the basic results of this chapter we have seen that industry GVA unambiguously raises with respect to its level if R&D is treated as an investment. This sometimes translates into higher growth rates, which is particular relevant for R&D intensive industries. Finally, the inclusion of R&D as investment in growth accounting leads to a more realistic calculation of TFP which has decreased in the shown example

[105] See section 3.3.4 in this work.

[106] For an econometric estimation strategy for private returns that are not biased by spillovers, see Eberhard et al. (2010).

[107] There is no apparent strong link between R&D capital intensity and the newly calculated TFP's by already considering the relevant pattern in the investigated industries (ISIC 24, 25, 30t33) .

in Slovenia due to the inclusion of this additional asset. Of course, the presented results for a limited number of industries can only be seen as a snapshot and need to be enlarged to a complete set of industries and to be aggregated to higher levels in order to get more reliable conclusions and in order to analyse the pattern of TFP in depth.

Throughout this chapter, it has been pinpointed to crucial assumptions of growth accounting that are especially relevant if R&D is considered as an additional type of investment. For example, it has been argued that the results will be very sensitive to a different depreciation pattern. Moreover, the marginalist principle of growth accounting will often be violated in a classical growth accounting framework due to the non-rival character of R&D investments. Nevertheless, an analysis of TFP's might also allow to identify spillover effects in a more sophisticated analysis that might be up for future research.

All in all, the treatment of R&D as an investment is absolutely necessary from a theoretical as well as from a practical point of view because otherwise policy makers might draw the wrong conclusions. Nevertheless, researchers and policy makers should keep in mind that the aimed inclusion of R&D in official national accounts should not lead to a careless use and interpretation of these data in a growth accounting framework.

Appendix to Chapter 1

Section 1.3: Double duopoly

To derive equation (1.5), we first differentiate the profit expressions in (1.3). For the firms located in country A this yields, using the first-order condition of the firms' optimal output choices $(p^i - r - t^A) = (p^i)' x_j^i \ \forall\, i$

$$\frac{d\pi_j}{dt^A} = x_j^A (p^A)' \left(\frac{dx^A}{dt^A} - \frac{dx_j^A}{dt^A} \right) + x_j^B (p^B)' \left(\frac{dx^B}{dt^A} - \frac{dx_j^B}{dt^A} \right) - x_j^A - x_j^B \quad \forall\, j = 1, 2 \ .$$

The firms located in country B face no direct effect of the tax increase so that

$$\frac{d\pi_j}{dt^A} = x_j^A (p^A)' \left(\frac{dx^A}{dt^A} - \frac{dx_j^A}{dt^A} \right) + x_j^B (p^B)' \left(\frac{dx^B}{dt^A} - \frac{dx_j^B}{dt^A} \right) \quad \forall\, j = 3, 4 \ .$$

Differentiating (1.4) with respect to t^A, using the above results and employing the symmetry conditions $(p^A)' = (p^B)' = p'$ and $x_j^i = x \ \forall i, j$ gives

$$-p' x_j^i \left[\alpha \sum_{i=A}^{B} \sum_{j=1}^{2} \frac{dx_j^i}{dt^A} + (1-\alpha) \sum_{i=A}^{B} \sum_{j=3}^{4} \frac{dx_i^j}{dt^A} + \frac{4(1-\alpha)}{p'} \right] = t^A \sum_{i=A}^{B} \sum_{j=1}^{2} \frac{dx_j^i}{dt^A} \ .$$

Adding and subtracting $(1-\alpha) \sum_{j=1}^{2} (dx_j^A/dt^A)$ and $\alpha \sum_{j=3}^{4} (dx_j^A/dt^A)$ in the square bracket and using $(dx_j^A/dt^A) = (dx_j^B/dt^A) \ \forall\, j$ gives equation (1.5).

With the demand function (1.6), the consumer surplus in (1.4) is $u(x^i) - px^i = (x^i)^2/2 \ \forall\ i$. Using (1.7) and substituting the resulting expression along with (1.8) into (1.4) yields:

$$\begin{aligned}\max_{t^A} W^A &= \frac{2}{25}[2(a-r)-t^A-t^B]^2+\frac{4}{25}\alpha[a-r-3t^A+2t^B]^2\\&+\frac{4}{25}(1-\alpha)[a-r-3t^B+2t^A]^2+t^A\frac{4}{5}[a-r-3t^A+2t^B]\ .\end{aligned}$$

The maximization problem of country B is analogous. This results in reaction functions

$$t^A=\frac{(a-r)(7-10\alpha)-t^B}{21-10\alpha},\qquad t^B=\frac{(a-r)(7-10\alpha)-t^A}{21-10\alpha},$$

and non-cooperative tax choices in the Nash equilibrium under double duopoly (subscript DD)

$$t^A_{(DD)}=t^B_{(DD)}=\frac{(a-r)(10\alpha^2-27\alpha+14)}{44+10\alpha^2-42\alpha}\ . \tag{A.1}$$

Substituting equilibrium tax rates in (A.1) back into (1.7) and (1.8) gives

$$x^i_{j(DD)}=\frac{(6-3\alpha)\,(a-r)}{2(22+5\alpha^2-21\alpha)}\quad\forall i,j\ ,\qquad \pi_{j(DD)}=\frac{(6-3\alpha)^2(a-r)^2}{2(22+5\alpha^2-21\alpha)^2}\quad\forall j\ . \tag{A.2}$$

Substituting (A.2) into the national welfare expressions (1.4) gives

$$W^A_{(DD)}=W^B_{(DD)}=\frac{(6-3\alpha)(a-r)^2(10\alpha^2-36\alpha+32)}{(22+5\alpha^2-21\alpha)^2}\ . \tag{A.3}$$

Equations (A.1) and (A.3) summarize tax policy and welfare in each country for different ownership structures, as captured by the parameter α.

Section 1.4: National merger

The firms' maximization problems are given by

$$\begin{aligned}\max_{x^A_{12},x^B_{12}}\pi_{12} &= (a-x^A)x^A_{12}+(a-x^B)x^B_{12}-(x^A_{12}+x^B_{12})(r-\sigma+t^A)\ ,\\ \max_{x^A_j,x^B_j}\pi_j &= (a-x^A)x^A_j+(a-x^B)x^B_j-(x^A_j+x^B_j)(r+t^B)\quad\forall\, j\in\{3,4\}\ .\end{aligned}$$

This leads to equilibrium outputs of

$$x_{12}^{i}=\frac{a-r+3\sigma+2t^{B}-3t^{A}}{4},\quad x_{3}^{i}=x_{4}^{i}=\frac{a-r-\sigma-2t^{B}+t^{A}}{4}\qquad i\in\{A,B\},\quad \text{(A.4)}$$

which lead to profits and consumer surplus equal to

$$\pi_{12}=\frac{1}{8}(a-r+3\sigma-3t^{A}+2t^{B})^{2},\qquad \pi_{3}=\pi_{4}=\frac{1}{8}(a-r-\sigma-2t^{B}+t^{A})^{2},\quad \text{(A.5)}$$

$$CS^{A}=CS^{B}=\frac{1}{32}[3(a-r)+\sigma-2t^{B}-t^{A}]^{2}. \quad \text{(A.6)}$$

Substituting these into the two governments' objective functions

$$W^{A}=CS^{A}+\alpha\pi_{12}+(1-\alpha)\sum_{j=3}^{4}\pi_{j}+t^{A}x_{12},\quad W^{B}=CS^{B}+\alpha\sum_{j=3}^{4}\pi_{j}+(1-\alpha)\pi_{12}+t^{B}\sum_{j=3}^{4}x_{j}$$

yields

$$\begin{aligned}
W^{A} &= \frac{1}{32}\left[3(a-r)+\sigma-t^{A}-2t^{B}\right]^{2}+\frac{\alpha}{8}\left(a-r+3\sigma-3t^{A}+2t^{B}\right)^{2}\\
&+\frac{(1-\alpha)}{4}(a-r-\sigma-2t^{B}+t^{A})^{2}+\frac{1}{2}t^{A}(a-r+3\sigma+2t^{B}-3t^{A}), \quad \text{(A.7)}\\
W^{B} &= \frac{1}{32}\left[3(a-r)+\sigma-t^{A}-2t^{B}\right]^{2}+\frac{\alpha}{4}(a-r-\sigma-2t^{B}+t^{A})^{2}\\
&+\frac{(1-\alpha)}{8}\left(a-r+3\sigma-3t^{A}+2t^{B}\right)^{2}+t^{B}(a-r-\sigma-2t^{B}+t^{A}). \quad \text{(A.8)}
\end{aligned}$$

This leads to Nash equilibrium tax rates

$$\begin{aligned}
t^{A}_{(NM)} &= \frac{(a-r)(19-40\alpha+16\alpha^{2})+\sigma(21-48\alpha+16\alpha^{2})}{2(27-30\alpha+8\alpha^{2})},\\
t^{B}_{(NM)} &= \frac{(a-r)(39-76\alpha+32\alpha^{2})+\sigma(9-12\alpha)}{2(54-60\alpha+16\alpha^{2})}. \quad \text{(A.9)}
\end{aligned}$$

From (A.9), eqs. (1.14) and (1.16) in the main text are obtained by setting $\alpha=1$ and $\alpha=0.5$, respectively. Moreover, substituting (A.9) into (A.7) and (A.8) and evaluating for $\alpha=1$ and $\alpha=0.5$, respectively, yields (1.15) and (1.17). Lastly, evaluating the profit expressions in (A.5) for the equilibrium tax rates (1.14) and (1.16) yields (1.18).

Section 1.5: Cross-border merger

The problem solved by the merged firm in the cross-border merger scenario is

$$\max_{x_{13}^A, x_{13}^B} \pi_{13} = \left(a - x^A\right) x_{13}^A + \left(a - x^B\right) x_{13}^B - x_{13}^A(r - s + t_A) - x_{13}^B(r - s + t_B).$$

Taking price discrimination and the symmetry of markets into account yields profits of all firms and consumer surplus equal to

$$\begin{aligned}
\pi_{13} &= \pi_{13}^A + \pi_{13}^B = \frac{1}{16}(a - r + 3s - 2t^A + t^B)^2 + \frac{1}{16}(a - r + 3s - 2t^B + t^A)^2 , \\
\pi_2 &= \pi_2^A + \pi_2^B = \frac{1}{16}(a - r - s + t^B - 2t^A)^2 + \frac{1}{16}(a - r - s - 3t^A + 2t^B)^2 , \\
\pi_4 &= \frac{1}{16}(a - r - s - 3t^B + 2t^A)^2 + \frac{1}{16}(a - r - s - 2t^B + t^A)^2 , \qquad \text{(A.10)}
\end{aligned}$$

$$CS^A = \frac{1}{32}\left[3\left(a - r\right) + s - 2t^A - t^B\right]^2 ; \; CS^B = \frac{1}{32}\left[3\left(a - r\right) + s - 2t^B - t^A\right]^2 . \qquad \text{(A.11)}$$

Using (A.10) and (A.11) in the objective functions of governments after a cross-border merger

$$\begin{aligned}
W^A &= 0.5(x^A)^2 + 0.5\pi_{13} + \alpha\pi_2 + (1 - \alpha)\pi_4 + t^A(x_2^A + x_2^B + x_{13}^A) , \\
W^B &= 0.5(x^B)^2 + 0.5\pi_{13} + \alpha\pi_4 + (1 - \alpha)\pi_2 + t^B(x_4^A + x_4^B + x_{13}^B)
\end{aligned}$$

yields for country A

$$\begin{aligned}
W^A &= \frac{1}{32}\left[3(a - r) + s - 2t^A - t^B\right]^2 + \frac{t^A}{4}\left[3(a - r) + s - 7t^A + 4t^B\right] \\
&+ \frac{1}{32}(a - r + 3s - 2t^A + t^B)^2 + \frac{1}{32}(a - r + 3s - 2t^B + t^A)^2 \\
&+ \frac{(1 - \alpha)}{16}(a - r - s + 2t^A - 3t^B)^2 + \frac{(1 - \alpha)}{16}(a - r - s - 2t^B + t^A)^2 \\
&+ \frac{\alpha}{16}(a - r - s - 2t^A + t^B)^2 + \frac{\alpha}{16}(a - r - s - 3t^A + 2t^B)^2 \qquad \text{(A.12)}
\end{aligned}$$

and analogously for country B. This yields Nash equilibrium tax rates

$$t_{(IM)}^A = t_{(IM)}^B = \frac{(a - r)(385 - 736\alpha + 256\alpha^2) + s(-245 + 672\alpha - 256\alpha^2)}{(1365 - 1184\alpha + 256\alpha^2)} . \qquad \text{(A.13)}$$

Substituting (A.13), for $\alpha = 1$ and $\alpha = 0.5$, back into (A.12) yields the welfare levels given in (1.20) and (1.22). Finally, from (A.10) and (A.13) we obtain (1.23).

Appendix to Chapter 2

Section 2.3: Results

Prices, profits and consumer surplus:

The profit maximizing problem of the firms in the benchmark scenario resulting in the produced quantities shown in (2.3) leads to the following equilibrium prices, profits and consumer surplus depending on tax rates:

$$p_{A(DD)} = p_{B(DD)} = a - x = \frac{1}{5}(a + 4r + 2k + 2t_A + 2t_B) \;;$$

$$\begin{aligned}
\pi_{1(DD)} &= \pi_{2(DD)} = \frac{2}{25}(a-r)^2 - \frac{2}{25}(a-r)(k + 6t_A - 4t_B) \\
&+ \frac{1}{25}(13k^2 + 6kt_A - 4kt_B + 18t_A^2 - 24t_At_B + 8t_B^2) \;, \\
\pi_{3(DD)} &= \pi_{4(DD)} = \frac{2}{25}(a-r)^2 - \frac{2}{25}(a-r)(k + 6t_B - 4t_A) \\
&+ \frac{1}{25}\left(13k^2 + 6kt_B - 4kt_A + 18t_B^2 - 24t_At_B + 8t_A^2\right) \;;
\end{aligned}$$

$$CS_{A(DD)} = CS_{B(DD)} = \frac{1}{2}(a - p_A)\,x = \frac{1}{2}\left(\frac{4}{5}a - \frac{4}{5}r - \frac{2}{5}k - \frac{2}{5}t_A - \frac{2}{5}t_B\right)^2 \;.$$

Analogously, in the cross-border merger scenario, using the respective optimal quantities in (2.6), one gets

$$\begin{aligned}
p_{A(IM)} &= a - x = \frac{1}{4}a + \frac{3}{4}r + \frac{1}{4}k + \frac{1}{2}t_A + \frac{1}{4}t_B \;, \\
p_{B(IM)} &= a - y = \frac{1}{4}a + \frac{3}{4}r + \frac{1}{4}k + \frac{1}{4}t_A + \frac{1}{2}t_B \;;
\end{aligned}$$

$$
\begin{aligned}
\pi_f &= \frac{1}{8}(a-r)^2 + \frac{2}{16}(a-r)(2k-t_A-t_B) \\
&\quad + \frac{1}{16}\left(2k^2 - 2kt_A - 2kt_B + 5t_A^2 - 8t_At_B + 5t_B^2\right) , \\
\pi_{2(IM)} &= \frac{1}{8}(a-r)^2 - \frac{2}{16}(a-r)(2k+5t_A-3t_B) \\
&\quad + \frac{1}{16}\left(10k^2 + 14kt_A - 10kt_B + 13t_A^2 - 16t_At_B + 5t_B^2\right) , \\
\pi_{4(IM)} &= \frac{1}{8}(a-r)^2 - \frac{2}{16}(a-r)(2k+5t_B-3t_A) \\
&\quad + \frac{1}{16}\left(10k^2 + 14kt_B - 10kt_A + 13t_B^2 - 16t_At_B + 5t_A^2\right) ;
\end{aligned}
$$

$$
CS_{A(IM)} = CS_{B(IM)} = \frac{1}{2}\left(\frac{3}{4}a - \frac{3}{4}r - \frac{1}{4}s - \frac{1}{2}t_A - \frac{1}{4}t_B\right)^2 .
$$

Inserting the equilibrium tax rates of the benchmark scenario shown in (2.9) into the respective results above I get

$$
p_A = p_B = r + \frac{1}{2}k
$$

as already stated in the main text. Benchmark profits are shown in (2.12) and consumer surplus can be calculated as

$$
CS_A = CS_B = \frac{1}{2}\left(r - a + \frac{1}{2}k\right)^2 .
$$

Analogously, using the optimal tax rates shown in (2.14) one gets with respect to the cross-border merger

$$
\begin{aligned}
p_A &= p_B = \frac{2}{23}a + \frac{21}{23}r + \frac{14}{23}k , \\
CS_A &= CS_B = \frac{1}{2}\left(\frac{21}{23}r - \frac{21}{23}a + \frac{14}{23}k\right)^2
\end{aligned}
$$

and profits as shown in (2.16) in the main text.

Production of the international merged firm in one country:

If firms are faced with tax rates favorising production exclusively in one country, the profit maximizing problem of the international merged firm must be adjusted by considering the corresponding tax rate on production as well as the additional trade cost for delivering to the other country. So, if $t_B > t_A + k$ holds, we have production exclusively in country A which leads to the following maximization problem of the merged firm f:

$$\begin{aligned}\max_{x_f, y_f} \pi_f &= (a - x_f - x_2 - x_4)\, x_f - x_f\,(r + t_A) \\ &\quad + (a - y_f - y_2 - y_4)\, y_f - y_f\,(r + t_A + k)\ .\end{aligned}$$

Thereby it underlies completely the local production tax rate.
Analogously, the international merged firm is producing exclusively in B if $t_A > t_B + k$. This implies

$$\begin{aligned}\max_{x_f, y_f} \pi_f &= (a - x_f - x_2 - x_4)\, x_f - x_f\,(r + t_B + k) \\ &\quad + (a - (y_f + y_2 + y_4)\, y_f - y_f\,(r + t_B)\,.\end{aligned}$$

There is no Nash equilibrium in this scenario as the only equilibrium candidate in the resulting non-cooperative tax competition game of national welfare maximizing governments does not fulfill the respective constraint stated above for each scenario. Intuitively, if the constraint $t_A > t_B + k$ was binding such that t_B is in fact a subsidy, there would be an incentive for the government in B to choose a lower subsidy: lowering the subsidy on the margin would incentivise the international merged firm to produce in both countries for the respective markets. Thereby the overall offer in B would be only marginally affected but country B would save on subsidies for all traded entities of the merged firm. As these subsidies are partly accruing to foreigners (as the owners of the international merged firm), the government would have a clear incentive to save on these expenses. Analogously, there would be an incentive to lower the tax rate in country A if the binding constraint $t_A > t_B + k$ had lead to a positive tax rate in A. The same analysis holds symmetrically for a hypothetical exclusive production of the mobile firm in country A.

Cost reductions and welfare implications:

The loss in national welfare must be smaller than privately necessary cost reductions in order to have a sufficient condition that any proposed international merger would be welfare increasing. Using (2.13), (2.16) and (2.17) it must hold

$$W_{i(IM)} - W_{i(DD)} = \left(-\tfrac{2}{529}\left(a-r\right)^2 + \tfrac{151}{1058}k(a-r) - \tfrac{1865}{4232}k^2\right) > (\pi_f - 2\pi_j)$$

$$\forall\ k \in \left[d; \tfrac{2}{1865}\left(a-r\right)\left(23\sqrt{29}+151\right)\right].$$

Thereby we have $(\pi_f - 2\pi_j) = \left(\frac{2}{529}\left(7a-7r+3k\right)^2 - \frac{1}{4}\left(r-a+\frac{1}{2}k\right)^2 - k^2\right)$. This condition can be simplified to

$$(\pi_f - 2\pi_j) = \tfrac{129}{2116}(a-r)^2 - \tfrac{563}{2116}k(a-r) + \tfrac{4975}{8464}k^2 > 0$$

which is fulfilled even for all positive values of k.

Appendix to Chapter 3

Appendix 3.1: Glossary of technical terms

Table A.3.1: Glossary of technical terms

Asset Types	**Definition**
Tangible capital	Stock of all assets recorded in existing national accounts, which includes ICT and software, transport vehicles, other machinery and equipment, residential structures, non-residential structures and other assets (e.g. live stock of plants and animals)
ICT and software	Computing equipment, communication equipment and software
Other machinery and equipment	Any equipment other than ICT and transport vehicles
Non-residential structures	Any building or infrastructure for non-residential use

Term	**Definition**
R&D investment	The part of a year's R&D expenditure that lives longer than one year and, hence becomes part of the R&D capital stock. Broadly in line with the new convention of the 2008 System of National Accounts, this ratio is assumed to be 100 percent.
R&D capital stock	The part of last year's capital stock that has not depreciated plus R&D investment of the current year.
R&D intensity	Ratio of R&D expenditure to value added (industry level or aggregate)
R&D capital intensity	Ratio of R&D capital stock to value added (industry level or aggregate)
Gap in R&D	Fact that one country has lower R&D intensity or lower R&D capital intensity
R&D capital ratio (with respect to total tangible capital)	Ratio R&D capital stock to total tangible capital stock
R&D capital ratio with respect to i	Ratio R&D capital stock to stock of tangible asset i
Triad	Countries consisting of the EU, the US and Japan
ISIC	International Standard Industrial Classification of All Economic Activities

Industries	**Definition**
Sector	Institutional sector
Industry	ISIC industry (one-letter, two-letter or two-digit)
ISIC 24	Chemicals and Pharmaceuticals
ISIC 30-33	ICT and other (non-transport) equipment
ISIC 34-35	Transport equipment

Appendix 3.2: Cross-country comparability of R&D data at the industry level

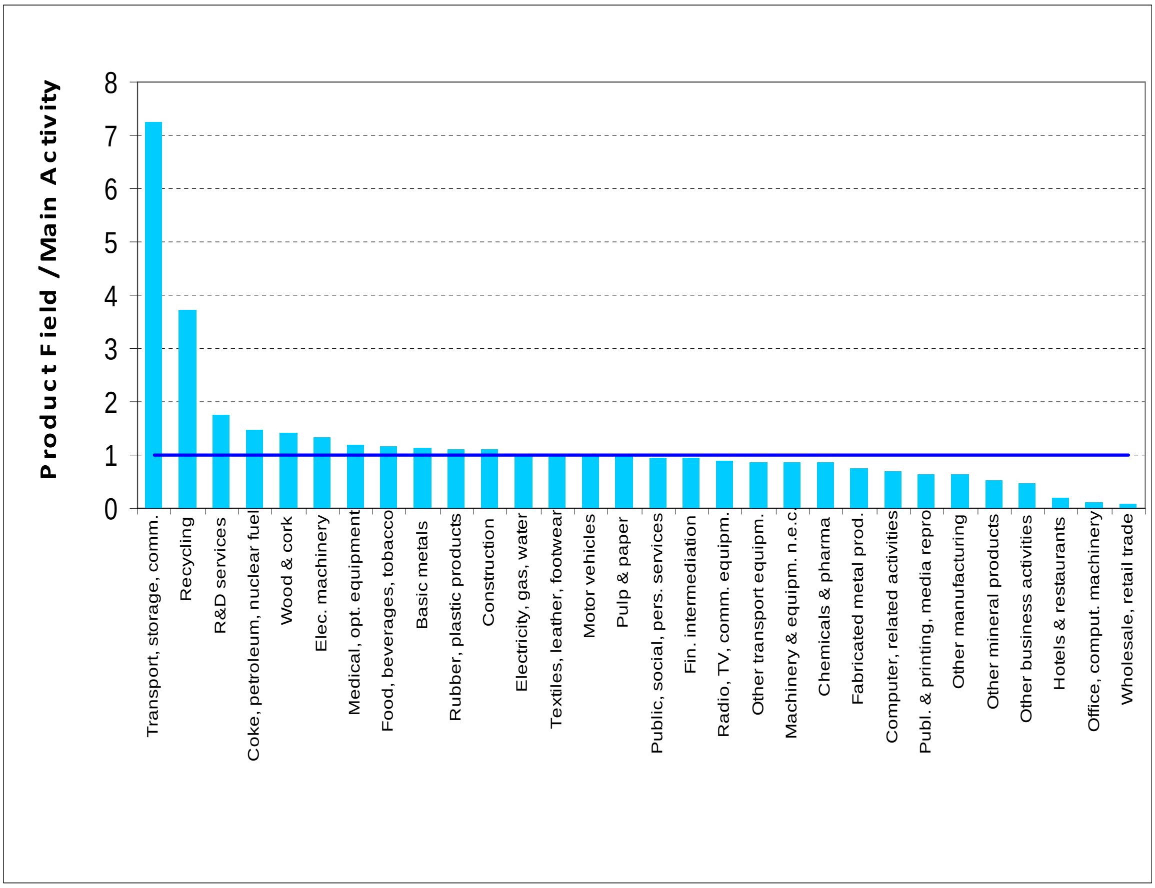
As stated in the main text, the comparability of industry-level R&D data is limited across countries because countries differ as to whether they follow the main-activity or the product-field approach in collecting R&D data from companies and compiling BERD at the industry level.

How to treat the R&D activity of a large multi-product enterprise in the compilation of R&D statistics by industry? Consider the example of a corporation which achieves 75 percent of its sales in steel production (ISIC 271) whereas the remainder of its sales constitutes special purpose machinery (ISIC 292). R&D expenditure can now either be allocated entirely to the main activity of the company (ISIC 271) or be divided between its two activities according to the actual R&D expenditure in both fields. In practice, both ways of allocating R&D expenditure across industries exist. Another problem is how to allocate the activity of the R&D services industry (ISIC 73). In a number of countries, the practice has changed over time. Furthermore, data may not be available on an annual basis and for all industries in certain countries (e.g. Austria), for example due to a lack of annual surveys or confidentiality issues (OECD 2009b).

While most of the R&D heavyweights among EU countries follow the product field approach, Japan and the US apply the main activity approach. For the US, this leads to significant amounts of R&D expenditure being recorded in service industries. For example, the main activity of IBM is business services because it achieves most of its turnover in that industry. But since most of its R&D is devoted to developing new ICT equipment, the current practice gives a missleading picture of the kind of R&D carried out.

The Czech Republic is the only country to publish data by product field and main activity (as from 2004). Figure A.3.1 shows the ratio of R&D expenditure by product field to that by main activity for 2005. For example, the economy spends seven times as much on R&D in the field of transport, storage and communication than the R&D expenditure by firms mainly active in this industry (ISIC 60-64) suggests. Turning to the most R&D-intensive industries, the differences are small for Chemicals and Pharmaceuticals and Transport equipment. In industry group ICT and other equipment, the main activity approach under-reports R&D in Electrical machinery and Medical and Optical equipment (ratio above 1) while it over-reports R&D in Radio and TV, Machinery n.e.c.. The difference is very large in Office and Computing machinery, the smallest industry in this group. All in all, differences are large for individual industries but using main activity R&D numbers is relatively unproblematic for R&D-intensive industry groups. However, there is no guarantee that these conclusions from the Czech example hold for other countries.

Figure A.3.1: Ratio of BERD by product field versus BERD by main activity, Czech Republic, 2005



Appendix 3.3: R&D expenditure in EU countries by institutional sector

Table A.3.2: R&D expenditure in EU countries by institutional sector

Country	Total			Business			Government and Higher education		
	1995-99	2000-03	2004-07	1995-99	2000-03	2004-07	1995-99	2000-03	2004-07
Belgium	1,8	2,0	1,9	1,3	1,4	1,3	0,5	0,6	0,6
Denmark	2,0	2,4	2,5	1,2	1,7	1,7	0,7	0,8	0,8
Germany	2,3	2,5	2,5	1,5	1,7	1,8	0,7	0,7	0,8
Ireland	1,3	1,1	1,3	0,9	0,8	0,8	0,4	0,3	0,4
Greece	0,5	0,6	0,6	0,1	0,2	0,2	0,4	0,4	0,4
Spain	0,8	1,0	1,2	0,4	0,5	0,6	0,4	0,4	0,5
France	2,2	2,2	2,1	1,4	1,4	1,3	0,8	0,8	0,8
Italy	1,0	1,1	1,1	0,5	0,5	0,5	0,5	0,6	0,6
Luxembourg	..	1,7	1,6	..	1,5	1,4	..	0,2	0,2
Netherlands	2,0	1,8	1,7	1,1	1,0	1,0	0,9	0,7	0,7
Austria	1,7	2,1	2,4	1,1	1,4	1,7	0,6	0,7	0,7
Portugal	0,6	0,8	0,9	0,1	0,2	0,4	0,5	0,5	0,5
Finland	2,7	3,4	3,5	1,8	2,4	2,5	0,9	1,0	1,0
Sweden	3,5	4,0	3,6	2,6	3,0	2,7	0,9	1,0	1,0
United Kingdom	1,8	1,8	1,7	1,2	1,2	1,1	0,6	0,6	0,7
EU-15	1,8	1,9	1,9	1,2	1,2	1,2	0,7	0,7	0,7
Bulgaria	0,6	0,5	0,5	0,2	0,1	0,1	0,4	0,4	0,4
Czech Republic	1,1	1,2	1,4	0,7	0,7	0,9	0,4	0,5	0,5
Estonia	0,6	0,7	1,0	0,1	0,2	0,5	0,5	0,5	0,6
Cyprus	0,2	0,3	0,4	0,0	0,1	0,1	0,2	0,2	0,3
Latvia	0,4	0,4	0,6	0,1	0,2	0,2	0,3	0,3	0,3
Lithuania	0,5	0,6	0,8	0,0	0,1	0,2	0,5	0,5	0,6
Hungary	0,7	0,9	0,9	0,3	0,4	0,4	0,4	0,6	0,5
Malta	..	0,3	0,6	..	0,1	0,4	..	0,2	0,2
Poland	0,7	0,6	0,6	0,3	0,2	0,2	0,4	0,4	0,4
Romania	0,4	0,4	0,4	0,3	0,2	0,2	0,1	0,1	0,2
Slovenia	1,4	1,4	1,5	0,7	0,8	0,9	0,7	0,6	0,6
Slovakia	0,9	0,6	0,5	0,5	0,4	0,2	0,3	0,2	0,3
EU-27	1,8	1,9	1,8	1,1	1,2	1,2	0,7	0,7	0,7
United States	2,6	2,7	2,6	1,9	1,9	1,9	0,7	0,8	0,8
Japan	2,9	3,1	3,3	2,0	2,3	2,5	0,9	0,8	0,8

Appendix 3.4: Assumptions made in computing R&D capital stocks

The construction of R&D capital stocks raises the same practical questions and difficulties that are known from the construction of tangible capital stocks. First, should all R&D expenditure be treated as investment? Second, the choice of the depreciation rate has an impact on the level of the R&D capital stock but little is known about the "service lives" of industrial R&D projects. Third, the initial R&D capital stock is unknown. A final problem is deflation: R&D investment of different years can only be added if adjusted for changes in the price of R&D over time. The remainder of this appendix discusses these issues in turn.

Capitalization rate:

It is assumed that 100 percent of R&D expenditure represents investment. At first glance, this seems to be a bold assumption. Nevertheless, business R&D is carried out mainly to increase profits in the medium and long term. R&D expenditure therefore fits the definition of investment as "any use of resources that reduces current consumption in order to increase it in the future" (Corrado et al. 2005, p. 19). Assuming that all R&D expenditure is undertaken to generate an economic benefit to the firm, it is justified to fully capitalize R&D expenditure. This is also in line with the guidelines of the System of National Accounts 2008.

Depreciation rate:

There is no consensus about the appropriate depreciation rate. We use a 12 percent rate that is constant across industries, countries and time. This assumption implies that if a country completely stopped investing in R&D, its R&D capital stock would be halved within five and a half years. We opt for this depreciation rate to be consistent with the existing R&D capital stock estimates of EU KLEMS on which we build (EU KLEMS 2008b, p. 12). Indeed, the choice of an appropriate rate is not straightforward as only few and divergent studies are available. A depreciation rate of 12 percent lies at the lower end of rates used in the literature. In an overview, Mead (2007) finds plausible rates between 12 and 20 percent. Van Ark et al. (2009) quote a range between 11 and 26 percent and use a rate of 20 percent in their estimates. This high variation in depreciation rates partly stems from different methods (e.g. patent renewal or market valuation models), none of them being completely satisfying. Moreover, in line with EU KLEMS (2008b) and van Ark et al. (2009), we do not account for potential differences in depreciation across industries, countries or over time because estimates in the literature are not converging. If anything, some tentative evidence is available for differences across industries. Starting in 2007, the US statistical authority has been writing off R&D capital in transport equipment somewhat faster (18 percent) and that in Chemicals and Pharmaceuticals somewhat more slowly (12 percent) than R&D capital in other industries, for which a rate of 15 percent is applied (Mead 2007).

Initial capital stock:

The initial capital stock is calculated by extrapolating R&D expenditure growth of the initial years back to the past. Ideally, one should use a long time series and assume an initial capital stock of zero. Since time series of R&D expenditure are relatively short, we follow the strategy used by EU KLEMS. We calculate the average expenditure growth rate of the first seven years with available data and assume that this growth rate prevailed in the past. Taking depreciation into account, an initial capital stock is calculated for the first year of available data. The impact on the initial capital stock of violating this assumption diminishes over time. To illustrate, assume that (i) the initial capital stock obtained through the described procedure is 100; (ii) the true (but unknown) initial stock is 120; and (iii) R&D expenditure is equal to 12 in every year with available data. In year 7, the measured R&D capital stock is still 100 while the true one has come down to 108, converging to 100 over time. To be on the save side, we do not show the R&D capital stocks obtained from the first seven years of R&D expenditure data.

Deflator of R&D expenditure:

As EUKLEMS, we use the GDP deflator. Alternatively, one could combine labour costs and output price indices of relevant industries in order to account for extraordinary productivity gains in "producing" R&D. For an overview and practical problems, see Fraumeni and Okubo (2005).

Appendix 3.5: Data sources and methods for the computation of R&D capital stocks

Our main data source for the construction of R&D capital stocks is the ANEBERD database of the OECD (2009b). This dataset contains R&D expenditure by industry performed in the business enterprise sector classified according to ISIC revision 3.1. ANBERD data are based on official data of business expenditure on R&D (henceforth OFFBERD), provided by national statistical authorities. In contrast to OFFBERD, ANBERD includes estimates for missing years as well as for industries that were suppressed for confidential reasons. The industry breakdown is quite detailed but must be used cautiously as there is some over- and underestimation in some countries where R&D expenditure data are not available on a product field basis (see subsection 3.2.2). This problem is relevant especially with respect to lower industry aggregates. The potential bias becomes smaller with aggregation over industries provided a bottom-up approach is applied (see below). In this chapter we only show aggregates of the main ISIC industries (one- and two-letter industries).

This aggregation over industries is also necessary in order to ensure compatibility with EU KLEMS data for R&D capital stocks up to 2003, which represent our second main data source. For a general description of the EU KLEMS project and databases see O'Mahony and Timmer (2009). EU KLEMS offers data for 13 EU countries (Belgium, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Poland, Spain, Sweden and UK), the US and Japan. EU KLEMS also used ANBERD data as their primary source. We replicate their methodology by using the Perpetual Inventory Method (described in appendix 3.4) for the construction of capital stocks out of current R&D expenditure, using the GDP deflator to obtain real expenditure.

With respect to data coverage, R&D capital stocks of EU KLEMS are available from 1980 onwards for all countries except Belgium (1994), the Czech Republic (1999) and Poland (2001). We update the EU KLEMS estimates using the newest ANBERD edition (covering years up to 2005 or 2006). Moreover, we add seven additional EU countries not available in the EU KLEMS database: Greece, Hungary, Austria, Portugal, Slovenia, Slovakia and Turkey. The time coverage of our additional countries is more limited due to the requirement of consistent R&D expenditure data for a sufficient period. More precisely, we have estimated an initial capital stock as early as possible (e.g. 1993 for Slovenia). As done by EU KLEMS, we suppress the first seven years due to their sensitivity to the estimated initial stock (see appendix 3.4). As a result of this suppression, our R&D capital stock estimates have the following starting years: 1995 for Greece and Portugal, 2000 for Slovenia, 2001 for Hungary, 2004 for Turkey and 2005 for Austria and Slovakia. For Slovakia, the limitation is that the R&D expenditure data of OECD (2009b) are in fact OFFBERD data with relatively low industry coverage.

As far as the aggregation of single industries to higher aggregates is concerned, we apply a bottom-up approach whenever sufficient industry information is available in order to avoid aggregation bias in the computation of initial capital stocks. Specifically, we calculate initial R&D capital stocks of two-letter ISIC industries to aggregate them to one-letter industries. Moreover, we use R&D capital stocks of one-letter industries in the computation of "total manufacturing" and "total services" but not for the overall computation of "total industries".

Finally, EU aggregates are computed as follows. For non-euro area members, all relevant variables (R&D capital stocks, tangible capital stocks and value added) at the aggregate and industry levels are converted into euros using average market exchange rates of the year 1999. Then the euro values for the available countries of EU-27 are added together separately for each variable, thereby ensuring that the same sample is used for the component variables of ratios. For example, the EU R&D capital stock used in computing the EU's R&D capital ratio comprises fewer countries than that used for the R&D capital intensity because tangible capital stocks are available for fewer countries.

Appendix to Chapter 4

Section 4.2: Framework of growth accounting with R&D as investment

Entries in national accounts depending on the status of R&D:

National income and production accounts distinguish between four activity accounts in order to capture all transactions in a closed economy. These are the production, income, capital and financing accounts which can be constructed on the microeconomic level as well as on the sectoral or national aggregate. This appendix shows how these accounts are affected by R&D depending on its status as investment or intermediate consumption. Therefore I consider an additional research project that is done with some additional labour input.

First, let us assume that this research project is not classified as investment. It is instead an intermediate input to another output, for example a chemical product. This project would show up on the microeconomic level of a company as follows: researchers have to be paid a loan which enters on the debit side of the production account. As the output of the research project cannot be capitalized, the project would not show up as own-account capital formation on the credit side of this account. This side consists essentially of sales, changes of inventories and own-account capital formation. Assuming that the research project increases the sales' value only in the long run, nothing would be added to the credit side. Now it must be ensured that also the debit side (to which the salaries of the researchers have been added) show the same sum as before. This can be ensured by adjusting the balance position on this side which are retained earnings. What does this imply for the calculation of gross value added (GVA) and gross domestic product (GDP)[108] from the income side? Respecting that retained

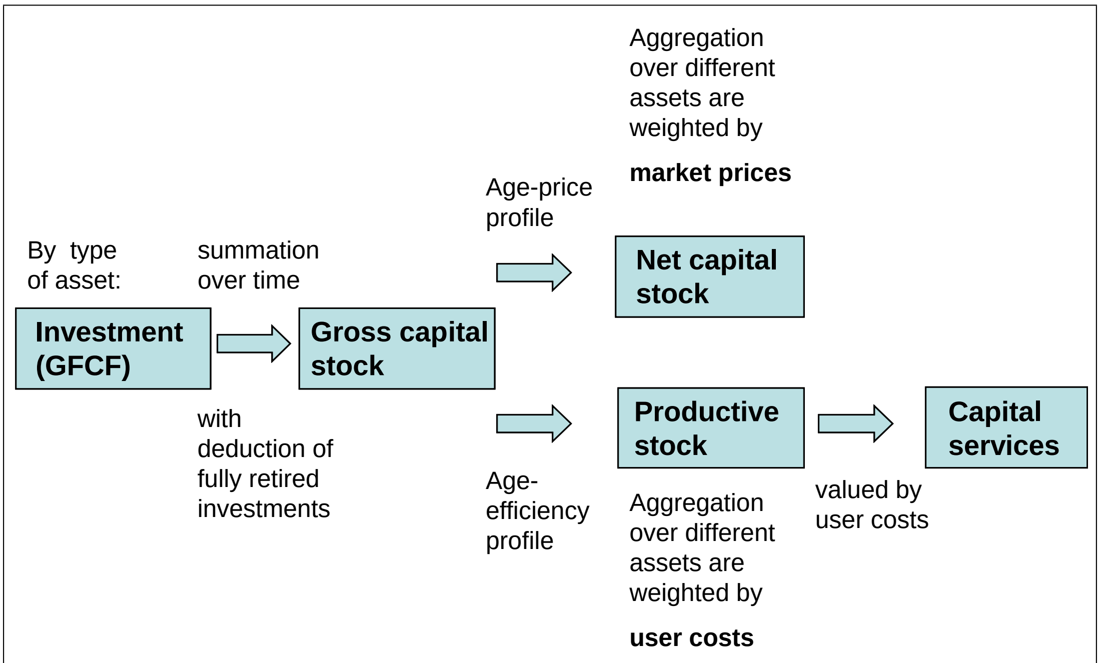
[108] GVA is linked to GDP by adding taxes and subtracting subsidies.

earnings and loans are both part of them, GDP is just unchanged by this additional research project as these two positions net out.

This picture changes if the research project was classified as investment: then also the credit side of the production account would change by adding the output of the research project as own-account capital formation analogously to a self-constructed machinery. This implies that the debit side must not be adjusted by lowering retained earnings and GDP will indeed increase in comparison to the initial treatment of the research project as intermediate consumption.

Let us also briefly discuss further implications to the other national accounts on the firm level: first, retained earnings on the debit side of the production account are equal to retained earnings on the credit side of the company's income account. Here the counterpart on the debit side are savings (after considering taxes). Therefore, higher retained earnings in the investment scenario result in higher savings. So, classification of R&D as investment increases national savings. Savings, in turn, show up on the credit side of the capital account. Finally, this account, which also includes own-account capital formation as part of gross fixed capital formation (investments) on the debit side, is simply enlarged identically on both sides if we treat the research project as investment. Therefore, the balance position, which is financial deficit or surplus, is unchanged in the capital account. This makes perfect sense as the company has activated a new investment which is conventionally evaluated at its investment costs. In contrast, if the project is treated as intermediate consumption, we get a lower financing surplus (or higher financing deficit) as the countervailing part on the debit side of the capital account. Finally, this financing deficit or surplus carries over inversely to the company's financing account.

Figure A.4.1: Capital stocks versus capital services



Source: own illustration, based on OECD (2009), p.24ff.

Section 4.4: Some first results for Slovenia and Germany

Table A.4.1: User cost of capital in 2006 (Euro), Slovenia

Asset	R&D treated as	Industry (ISIC)		
		25	29	30t33
R&D	intermediate	-	-	-
	investment	*0,38*	*0,37*	*0,36*
IT	intermediate	0,32	0,31	0,31
	investment	*0,31*	*0,31*	*0,31*
CT	intermediate	0,30	0,29	0,29
	investment	*0,30*	*0,29*	*0,28*
Soft	intermediate	0,66	0,65	0,65
	investment	*0,65*	*0,64*	*0,64*
TraEq	intermediate	0,46	0,41	0,38
	investment	*0,45*	*0,40*	*0,36*
Omach	intermediate	0,28	0,26	0,27
	investment	*0,27*	*0,25*	*0,25*
Ocon	intermediate	0,25	0,24	0,24
	investment	*0,24*	*0,22*	*0,22*
RStruc	intermediate	0,18	0,16	0,16
	investment	*0,17*	*0,15*	*0,14*
Other	intermediate	0,44	0,41	0,40
	investment	*0,43*	*0,39*	*0,37*

Table A.4.2: User cost of capital in 2006 (Euro), Germany

Asset	R&D treated as	Industry (ISIC)		
		25	29	30t33
R&D	intermediate	-	-	-
	investment		*0,91*	*0,22*
IT	intermediate	0,10	0,11	0,09
	investment	*0,10*	*0,13*	*0,08*
CT	intermediate	0,26	0,29	0,22
	investment	*0,23*	*0,38*	*0,18*
Soft	intermediate	0,47	0,51	0,42
	investment	*0,44*	*0,61*	*0,36*
TraEq	intermediate	0,43	0,46	0,34
	investment	*0,39*	*0,59*	*0,27*
Omach	intermediate	0,35	0,39	0,28
	investment	*0,31*	*0,52*	*0,21*
Ocon	intermediate	0,21	0,28	0,19
	investment	*0,17*	*0,40*	*0,12*
RStruc	intermediate	-	-	-
	investment	-	-	-
Other	intermediate	0,28	0,31	0,23
	investment	*0,25*	*0,40*	*0,18*

Source: EU KLEMS, own calculations

Notes: - User costs for the scenario with R&D as intermediates have been computed using the recalculated nominal rate of return of table 4.1 in order to ensure consistency.
- ISIC 24 is not shown due to data problems with residential structures in Slovenia.

Table A.4.3: Logarithmic growth of capital services in ISIC 30t33 (in %), Slovenia 2001-2006

Asset	**R&D treated as**	**Year**					
		2001	2002	2003	2004	2005	2006
R&D	intermediate	-	-	-	-	-	-
	investment	*10,09*	*7,54*	*6,36*	*5,47*	*5,37*	*4,71*
ICT	intermediate	19,33	0,76	3,57	2,14	3,18	0,29
	investment	*19,48*	*0,77*	*3,64*	*2,23*	*3,30*	*0,32*
Non-ICT	intermediate	10,91	9,33	8,68	7,05	8,31	5,49
	investment	*10,98*	*9,34*	*8,74*	*7,24*	*8,50*	*5,56*

Table A.4.4: Logarithmic growth of capital services in ISIC 30t33 (in %), Germany 2001-2006

Asset	**R&D treated as**	**Year**					
		2001	2002	2003	2004	2005	2006
R&D	intermediate	-	-	-	-	-	-
	investment	*0,86*	*0,18*	*-0,19*	*-0,10*	*-0,27*	*0,76*
ICT	intermediate	13,34	3,98	0,47	-1,12	2,82	7,62
	investment	*13,45*	*3,95*	*0,47*	*-1,11*	*2,91*	*7,79*
Non-ICT	intermediate	5,37	0,11	-1,25	-0,39	-0,20	0,48
	investment	*5,41*	*0,13*	*-1,25*	*-0,42*	*-0,16*	*0,53*

Source: EU KLEMS, own calculations

Notes: User costs for the scenario with R&D as intermediates have been computed using the recalculated nominal rate of return of table 4.1 in order to ensure consistency.

Table A.4.5: Growth contributions in Electrical and Optical Equipment (ISIC 30t33) with and without R&D as investment (in %), Germany 2001-2006

Asset	R&D treated as	Year					
		2001	2002	2003	2004	2005	2006
All (real	intermediate	-9,27	0,95	6,11	10,91	4,00	12,63
GVA growth)	*investment*	*-6,60*	*0,38*	*5,33*	*10,19*	*3,98*	*12,56*
R&D	intermediate	-	-	-	-	-	-
	investment	*0,10*	*0,02*	*-0,02*	*-0,01*	*-0,04*	*0,12*
ICT	intermediate	0,38	0,10	0,01	-0,03	0,09	0,23
	investment	*0,36*	*0,10*	*0,01*	*-0,02*	*0,07*	*0,19*
Non-ICT	intermediate	0,57	0,01	-0,17	-0,07	-0,04	0,10
	investment	*0,52*	*0,01*	*-0,13*	*-0,05*	*-0,02*	*0,07*
Labour	intermediate	0,65	-3,14	-3,31	1,85	-2,52	1,20
	investment	*0,57*	*-2,78*	*-2,95*	*1,66*	*-2,27*	*1,08*
TFP	intermediate	-10,86	3,98	9,58	9,16	6,47	11,10
	investment	*-8,15*	*3,04*	*8,43*	*8,61*	*6,23*	*11,10*

Source: own (re)calculations, based on EU KLEMS and Helmers et al. (2009)

Notes: The contribution of labour also contains changes in the composition of labour.

Literature to Chapter 1

Barros, P.P. and L. Cabral (1994), Merger policy in open economies. *European Economic Review 38*, 1041-1055.

Bjorvatn, K. (2004), Economic integration and the profitability of cross-border mergers and acquisitions. *European Economic Review 48*, 1211-1226.

Becker, J. and C. Fuest (2009), Source versus residence based taxation with international mergers and acquisitions. *CESifo Working Paper No. 2854.* Munich.

Becker, J. and C. Fuest (2010), Taxing foreign profits with international mergers and acquisitions. *International Economic Review 51*, 171-186.

Brander, J.A. (1995), Strategic trade policy. In: G. Grossman and K. Rogoff (eds.), *Handbook of international economics, vol. III*, 1395-1455. Elsevier, Amsterdam and New York.

Denis, C., H. Huizinga and G. Nicodème (2005), Foreign ownership in Europe: Determinants and taxation consequences. In: H. Huizinga and L. Jonung (eds.), *The internationalisation of asset ownership in Europe*, 110-139. Cambridge University Press, Cambridge.

European Union (2004), Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentration between undertakings. *Official Journal of the European Union 2004/C31/03* (5 February 2004), Brussels.

Focarelli, D. and A.F. Pozzolo (2001), The patterns of cross-border bank mergers and shareholdings in OECD countries. *Journal of Banking and Finance 25*, 2305-2337.

Fuest, C. (2005), Economic integration and tax policy with endogenous foreign firm ownership. *Journal of Public Economics 89*, 1823-1840.

Gugler, K., D.C. Mueller, B. Yurtoglu and Ch. Zulehner (2003), The effects of mergers: An international comparison. *International Journal of Industrial Organization 21*, 625-653.

Head, K. and J. Ries (1997), International mergers and welfare under decentralized competition policy. *Canadian Journal of Economics 30*, 1104-1123.

Hashimzade, N., H. Khodavaisi and G.D. Myles (2005), Tax principles, product differentiation and the nature of competition. *International Tax and Public Finance 12*, 695-712.

Haufler, A. and S.B. Nielsen (2008), Merger policy to promote 'global players'? A simple model. *Oxford Economic Papers 60*, 517-545.

Haufler, A., G. Schjelderup and F. Stähler (2005), Barriers to trade and imperfect competition: The choice of commodity tax base. *International Tax and Public Finance 12*, 281-300.

Hijzen, A., H. Görg and M. Manchin (2008), Cross-border mergers and acquisitions and the role of trade costs. *European Economic Review 2008*, 849-866.

Huizinga, H. and G. Nicodème (2006), Foreign ownership and corporate income taxation: An empirical evaluation. *European Economic Review 2006*, 1223-1244.

Huizinga, H. and S.B. Nielsen (1997), Capital income and profit taxation with foreign ownership of firms. *Journal of International Economics 42*, 149-165.

Horn, H. and J. Levinsohn (2001), Merger policies and trade liberalization. *Economic Journal 111*, 244-276.

Horn, H. and L. Persson (2001), The equilibrium ownership of an international oligopoly. *Journal of International Economics 53*, 307-333.

Huck, S. and K.A. Konrad (2004), Merger profitability and trade policy. *Scandinavian Journal of Economics 106*, 107-122.

Janeba, E. (1998), Tax competition in imperfectly competitive markets. *Journal of International Economics 44*, 135-153.

Keen, M. and S. Lahiri (1998), The comparison between destination and origin principles under imperfect competition. *Journal of International Economics 45*, 323-350.

Keen, M., S. Lahiri and P. Raimondos-Møller (2002), Tax principles and tax harmonization under imperfect competition: A cautionary example. *European Economic Review 46*, 1559-1568.

Lommerud, K.E., O.R. Straume and L. Sørgard (2006), National versus international merger in unionised oligopoly. *Rand Journal of Economics 37*, 212-233.

Mueller, D. (1997). Merger policy in the United States: A reconsideration. *Review of Industrial Organization 12*, 655-685.

Pinkowitz, L., M. Dahlquist, R. Stulz and R. Williamson (2003), Corporate governance and the home bias. *Journal of Financial and Quantitative Analysis 38*, 87-110.

Richardson, M. (1999), Trade and competition policies: Concordia discors? *Oxford Economic Papers 31*, 649-664.

Röller, L.-H, J. Stennek and F. Verboven (2001), Efficiency gains from mergers. *European Economcy 5*, 32-128.

Saggi, K. and H. Yildiz (2006), On the international linkages between trade and merger policies. *Review of International Economics 14*, 212-225.

Salant, S.W., S. Switzer and R.J. Reynolds (1983), Losses from horizontal merger: The effects of an exogenous change in industry structure on Cournot-Nash equilibrium. *Quarterly Journal of Economics 98*, 185-199.

Südekum, J. (2008), Cross-border mergers and national champions in an integrating economy. *Journal of Institutional and Theoretical Economics 164*, 477-508.

UNCTAD (2007), World investment report 2007. New York.

Literature to Chapter 2

Andersen, J.E. and E. van Wincoop (2004), Trade costs. *Journal of Economic Literature 42*, 691-751.

Brander, J. and K. Krugman (1983), A 'reciprocal dumping' model of international trade. *Journal of International Economics 15*, 313-321.

Hashimzade, N., H. Khodavaisi and G.D. Myles (2005), Tax principles, product differentiation and the nature of competition. *International Tax and Public Finance 12*, 695-712.

Haufler, A. and S.B. Nielsen (2008), Merger policy to promote 'global players'? A simple model. *Oxford Economic Papers 60*, 517-545.

Haufler, A. and C. Schulte (2009), Merger policy and tax competition, the role of foreign ownership, Manuscript. Revised version of Merger policy and tax competition, *CESifo Working Paper 2157.*

Haufler, A., G. Schjelderup and F. Stähler (2005), Barriers to trade and imperfect competition: The choice of commodity tax base. *International Tax and Public Finance 12*, 281-300.

Hoeckman, B., W. Martin and A. Mattoo (2009), Conclude Doha, it matters! *The World Bank, Policy Research Working Paper 5135.*

A. Hijzen,Gorg, G. and M. Manchin (2008), Cross-Border Mergers and Acquisitions and the Role of Trade Costs. *European Economic Review 52*, 849-866.

Huck, S. and K.A. Konrad (2004), Merger profitability and trade policy. *Scandinavian Journal of Economics 106*, 107-122.

Rossi, S. and P.F: Volpin (2004), Cross-country determinants of mergers and acquisitions. *Journal of Financial Economics 74*, 277-304.

Salant, S.W., S. Switzer and R.J. Reynolds (1983), Losses from horizontal merger: The effects of an exogenous change in industry structure on Cournot-Nash equilibrium. *Quarterly Journal of Economics 98*, 185-199.

Südekum, J. (2008), Cross-border mergers and national champions in an integrating economy. *Journal of Institutional and Theoretical Economics 164*, 477-508.

Saggi, K. and H. Yildiz (2006), On the international linkages between trade and merger policies. *Review of International Economics 14*, 212-225.

United Nations Conference on Trade and Development (2009). *World Investment Report 2009*, available online at www.unctad.org.

Literature to Chapter 3

Acemoglu, D., Zilibotti, F., and Aghion, P. (2006), Distance to Frontier, Selection, and Economic Growth. *Journal of the European Economic Association 4*, 37-74.

Arrow, K. (1962), Economic Welfare and the Allocation of Resources for Inventions. In Nelson, R. (ed.), *The Rate and Direction of Inventive Activity*, Princeton University Press, Princeton, USA.

Cameron, G., Proudman, J. and Redding, S. (2005), Technological Convergence, R&D, Trade and Productivity Growth. *European Economic Review 49*, 775-807.

Bontempi, M.E. and Mairesse, J. (2008), Intangible capital and productivity: An exploration on a panel of Italian manufacturing firms. *NBER Working Paper No. 14108*, National Bureau of Economic Research.

Cohen, W.M. and Levinthal, D.A. (1989), Innovation and learning: the two faces of R&D. *The Economic Journal 99*, 569-596.

Corrado, C., Hulten, C. and Sichel, D. (2005), Measuring Capital and Technology – An Expanded Framework. In Corrado, C., Haltiwanger, J. and Sichel, D. (eds.), *Measuring Capital in the New Economy.* NBER Studies in Income and Wealth Volume 65*, Chapter 1*, University of Chicago Press, Chicago.

Danguy, J., de Rassenfosse, G. and van Pottelsberghe de la Poterie, B. (2009), The R&D-patent relationship: An industry perspective. *EIB Papers 14*, 170-195.

D'Auria, F., Pagano., A., Ratto, M. and Varga, J. 2009, A comparison of structural reform scenarios across the EU member states – Simulation-based analysis using the QUEST model with endogenous growth. *European Economy Economic Papers No. 392*, European Commission, DG ECFIN.

Eberhardt, M., Helmers, C. and Strauss, H. (2010), Do spillovers matter when estimating private returns to R&D? *Economic and Financial Report 01/2010*, European Investment Bank.

EU KLEMS (2008a), EU KLEMS Database March 2008 Release. See: Timmer, M., M. O'Mahony and B. van Ark, The EU KLEMS Growth and Productivity Accounts: An Overview. *University of Groningen & University of Birmingham*, http://www.euklems.net/index.html.

EU KLEMS (2008b), EU KLEMS Linked Data 2008 Release. See: O'Mahony, M. et al., EU KLEMS Linked Data, Sources and Methods. *University of Birmingham*, November 2008, http://www.euklems.net/linked.shtml.

European Commission, IMF, OECD, UN, World Bank (2009), System of National Accounts 2008. New York http://unstats.un.org/unsd/nationalaccount/sna2008.asp.

Fraumeni, B.M. and Okubo, S. (2005), R&D in the National Income and Product Accounts – A first look at its effects on GDP. In Corrado, C., Haltiwanger, J. and Sichel, D. (eds.), Measuring Capital in the New Economy. *NBER Studies in Income and Wealth Volume 65*, University of Chicago Press, Chicago.

Griffith, R., Redding, S. and van Reenen, J. (2003), R&D and Absorptive Capacity: Theory and Empirical Evidence. *Scandinavian Journal of Economics, 105*, 99-118.

Griffith, R., Redding, S. and van Reenen, J. (2004), Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Countries. *Review of Economics and Statistics, 86*, 883-895.

Griliches, Z. (1979), Issues in assessing the contribution of research and development to Productivity Growth. *The Bell Journal of Economics, 10*, 92-116.

Griliches, Z. and Lichtenberg, F. (1984), R&D and Productivity Growth at the Industry Level: Is there Still a Relationship?. In Griliches, Z. (ed.), *R&D, Patents and Productivity.* University of Chicago Press, Chicago.

Grossman, G. and Helpman, E. (1991), Innovation and Growth in the Global Economy. *MIT Press, Cambridge MA.*

Guellec, D. and van Pottelsberghe de la Poterie, B. (2004), From R&D to Productivity Growth: Do Institutional Settings and the Source of Funds Matter? *Oxford Bulletin of Economics and Statistics, 66*, 353-378.

Mead, C.I. (2007), R&D Depreciation Rates in the 2007 Satellite Account. *Bureau of Economic Analysis and National Science Foundation*, Washington, D.C..

OECD (2009a), Measuring Capital. *OECD Manual, Second edition*, Organisation for Economic Co-operation and Development, Paris.

OECD (2009b), ANBERD (Analytical Business Enterprise Research and Development) *Database 2009.* Organisation for Economic Co-operation and Development, Paris. www.oecd.org/sti/anberd – Data available at: *http://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV3.*

O'Mahony, M. and Timmer, M. (2009), Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database. *The Economic Journal, 119*, F374-F403.

Romer, D. (1990), Endogenous Technological Change. *Journal of Political Economy, 98*, 71-101.

Solow, R.M. (1956), A contribution to the theory of economic growth. *Quarterly Journal of Economics, 70*, 65-94.

Uppenberg, K. (2009a), Innovation and growth. *EIB Papers, 14*, 10-35.

Uppenberg, K. (2009b), R&D in Europe: Expenditures across Sectors, Regions and Firm Sizes. *Centre for European Policy Research*, Brussels.

van Ark, B., Hao, J., Corrado, C. and Hulten, C. (2009), Measuring intangible capital and its contribution to economic growth in Europe. *EIB Papers, 14*, 62-93.

Literature to Chapter 4

Van Ark, B. et al. (2009), Measuring Intangible Capital and its Contributions to Economic Growth in Europe. *EIB papers 14*, 64-94.

Barro, R.J. (1999), Notes on Growth Accounting. *Journal of Economic Growth 4*, 119-137.

Corrado, C., C. Hulten and D. Sichel (2005), Measuring Capital and Technology: An Expanded Framework. In: Corrado et al, Measuring Capital in the New Economy. *NBER Studies in Income and Wealth 65*, 11-45. University of Chicago Press, Chicago.

Corrado, C., C. Hulten and D. Sichel (2009), Intangible Capital and Economic Growth. *Review of Income and Wealth 55*, 661-685.

Eberhard, M., C.Helmers and H.Strauss (2010), Do Spillovers Matter When Estimating Private Returns to R&D?. *EIB Economic and Financial Reports 01/2010*, European Investment Bank.

EU KLEMS (2008a), EU KLEMS Database March 2008 Release. See: Timmer, M., M. O'Mahony and B. van Ark, The EU KLEMS Growth and Productivity Accounts: An Overview. *University of Groningen & University of Birmingham*, http://www.euklems.net/index.html.

EU KLEMS (2008b), EU KLEMS Linked Data 2008 Release. See: O'Mahony, M. et al., EU KLEMS Linked Data, Sources and Methods. *University of Birmingham*, November 2008, http://www.euklems.net/linked.shtml.

EU KLEMS (2009), EU KLEMS Database November 2009 release. See: O'Mahony, M. and M.P. Timmer, Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database. *Economic Journal 119*, 374-403, http://www.euklems.net/index.html.

EU KLEMS Growth and Productivity Accounts (2007), Methodology and Sources, prepared by M. Timmer et al.. *EU KLEMS consortium*, available online at www.euklems.net.

Erumban, A. (2008), Capital Aggregation and Growth Accounting: A Sensitivity Analysis, *EU KLEMS Working Paper 25.*

European Commission, IMF, OECD, UN, World Bank (2009), System of National Accounts 2008. New York, http://unstats.un.org/unsd/nationalaccount/sna2008.asp.

European Commission, IMF; OECD, UN, World Bank (1993), System of National Accounts 1993. New York, available online at http://unstats.un.org/unsd/sna1993/introduction.asp.

Fraumeni, B. (1997), The Measurement of Depreciation in the US National Income and Product Accounts, *Survey of Current Business,* 7-23.

Fraumeni, M. and S. Okubo (2005), R&D in the National Income and Product Accounts, A First Look at Its Effect on GDP. In:Corrado et al, Measuring Capital in the New Economy. *NBER Studies in Income and Wealth 65,* 275- 322.

Fukao, K., Hamagata, S., Miyagawa, T. and Tonogi, K. (2009). Intangible Investment in Japan: Measurementand Contribution to Economic Growth. *The Review of Income and Wealth 553*, 717-736.

Hao, J.X., Manole, V. and van Ark, B. (2009). Intangible Capital and Economic Growth – an International Comparison. *COINVEST project paper*, available online at www.coinvest.org.uk.

Helmers, C., C. Schulte and H. Strauss (2009), Business R&D expenditure and capital in Europe. *EIB papers 14*, 36-61.

Jorgenson, D.W. and Z.Grilliches (1967), The Explanation of Productivity Change. *The Review of Economic Studies 34*, 249-283.

Marrano, M.G., Haskel, J. and Wallis, G. (2009). What happened to the knowledge economy? ICT, intangible investment and Britain's productivity record revisited. *The Review of Income and Wealth 553*, 686-716.

Mead, C.I. (2007), R&D Depreciation Rates in the 2007 Satellite Account. *Bureau of Economic Analysis and National Science Foundation*, Washington D.C..

Nordhaus, W. (1997), Do real-output and real-wage measures capture reality? The history of lighting suggests not. In: T.Bresnahan and R.Gordon (eds), *The economics of new goods*, 29-66. University of Chicago Press, Chicago.

OECD (2009), Measuring capital. *OECD manual 2009, second edition*, available online at www.oecd.org.

Powell, W. and K.Snellman (2004), The Knowledge Economy. *Annual Review of Sociology 30*, 199-220.

Roehn, O., T.S. Eicher and T. Strobel (2007), The Ifo Industry Growth Accounting Database. *CESifo Working Paper Series 1915.*

Sveikauskas, L. (2007), R&D and Productivity Growth: A Review of the Literature. *Bureau of Labour Statistics Working Paper 408.*

Solow, R.M. (1957), Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics 39*, 312-320.

Timmer, M.P., Ypma, G. and B. van Ark (2003), IT in the European Union: Driving Productivity Divergence? *Groningen Growth and Development Centre Research Memorandum GD-67*, Groningen: University of Groningen, Appendix Tables, updated June 2005.

Eidesstattliche Versicherung

Ich versichere hiermit eidesstattlich, dass ich die vorliegende Arbeit selbständig und ohne fremde Hilfe verfasst habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sowie mir gemachte Anregungen sind als solche kenntlich gemacht.

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