INNOVATIVE ON TRADE:

An Empirical Analysis of the Relationship between Trade Innovation and Productivity

Thesis MSc. Economics

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Abstract This paper analyzes the effect of innovation that lowers transaction costs - *trade innovation* - on productivity increases of thirteen OECD-countries by using export intensity as proxy. A panel data approach is used to distill the effects of trade and technological innovation on productivity for the period 1981 -2007. The analysis shows that trade innovation is indeed an important determinant of productivity. Especially trade-oriented countries seem to have benefited from innovative efforts on trade while more on production oriented countries have spurred their productivity by means of technological innovation.

Keywords Total Factor Productivity, R&D, Innovation, Transaction Costs, Trade Innovation, Export Intensity, Technological Spillover Effects, Human Capital, Openness

JEL Classifications F10, F43, O47

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1. Introduction

Innovation is in general associated with the creation of new or better products, processes or technologies. Joseph Schumpeter is seen as the first economist to draw attention to the importance of innovation for societies, he identified five types of innovation (OECD Oslo Manuel, 1995).[2] Schumpeter argued that firms innovate because they are seeking rents and innovation creates some sort of advantage for the innovator which enables him to extract these rents.

The debate on innovation is dominated by the notion that only innovative efforts on research and development (R&D) yield positive benefits for society in terms of economic growth. This explains the aim of the European Union, as mapped out in the Lisbon Strategy in 2000, to invest 3% of income on R&D. In this narrow view of the relationship between innovation and economic growth, other forms of innovation that positively affect productivity are neglected. In the current worldwide fragmentation of production, productivity gains stem from two different sources, namely (i) more efficiency *within* parts of the production chain through product or process innovation associated with investments in R&D, and (ii) more efficiency *between* parts of the production chain through better organization of production and lowering of transaction costs.

This paper tries to highlight the importance of innovation that lowers transaction costs – which is referred to as *trade innovation* – and has a positive effect on productivity through the channel of trade. This paper contributes to the existing literature on two different ways. First, the concept of innovation and the relationship between innovation and productivity is broadened by empirically assessing this link using time series data of thirteen OECD countries. Second, as not much research has been performed on the effect of trade innovation, this study contributes to the measurement problem of innovative efforts on trade by introducing a new proxy for trade innovation.

[2] These five types are: introduction of a new product or a qualitative change in an existing product; process innovation new to an industry; the opening of a new market; development of new sources of supply for raw materials or other inputs; changes in industrial organization.

The effect of trade and technological innovation on productivity of thirteen OECD countries in the period 1981 – 2007 is analyzed by means of a panel data approach. The empirical analysis is aimed at studying i) to what extent trade innovation has been important in explaining productivity and ii) the effect of trade innovation on productivity for trade-oriented and production-oriented countries in particular.

The analysis shows promising results and rejects the one-size-fits-all strategy of the European Commission. First, trade innovation seems to have been an important determinant of productivity and trade-oriented countries in particular appear to have benefited from innovation that lowers transaction costs. Production-oriented countries seem to enhance their productivity by means of investing in R&D.

These findings negate the narrow view of only investing in technological innovation in order to enhance economic growth. Furthermore, this paper confirms the positive effect of human capital and the benefits of technological spillovers. The main implication for policy that is being sketched by this paper is that government policy on innovation should be broad and coherent.

The remainder of this research is structured as follows:

Section 2 discusses the theoretical considerations and provides a literature review. Section 3 explains the model, its assumptions and variables. Section 4 discusses the data. Thereafter, the data is statistically analyzed in Section 5. The empirical analysis is conducted in Section 6, and Section 7 concludes and discusses policy implications and suggestions for further research.

2. Literature Review

Trade fosters growth, this relation, which is in general acknowledged by economists and empirically analyzed in various studies, implies that countries that increase their trade level could have an additional source of economic growth. In the current economic constellation in which transaction costs comprise a large part of economic activity, lowering these costs could enhance a country's trade level. Transactions costs can be lowered by trade innovation which promotes further specialization and division of labor. But, what are transaction costs and how can trade innovation lead to lower transaction costs? This section provides a literature review on these and related topics. At first, the notion of trade management and trade innovation will be briefly discussed. After that, this chapter continues with explaining transaction costs and their importance in our economic system. Thereafter, the link between trade and economic growth is addressed. A review of the empirical relation between innovation and economic growth concludes this section.

i. Transaction Management and Trade Innovation

World trade, defined as total imports and exports of all countries, has redoubled several times in the previous decades. This rapid increase in international trade, which is spurred by elevations in technology that have decreased the costs of trade over time, is characterized as globalization (Coe *et al*. 2002). The decline in *relative* distances, represented by decreasing costs of trade, has made off shoring and outsourcing accessible to more firms. As a result, production processes in a vertical chain stretch out across many countries, with each country specializing in particular stages of a good's production cycle. This increased interconnectedness is referred to as *vertical specialization* by Hummels *et al.* (2001). In their study on the nature and growth of vertical specialization in world trade they show that international vertical specialization of the production process, i.e. off shoring, has increased with 30% between 1970 and 1990.

The increased fragmentation of the production process, or ''unbundling" (Baldwin, 2006, 2011), has changed the conventional activities of firms; instead of producing all components of a final product, firms nowadays link and connect the individual chains of production to each other. The focus in this *orchestrating* function aims to exploit all advantages of specialization and fragmentation of the production as good as possible (Den Butter 2010). An orchestrating function is accompanied by more *transaction costs*. Orchestrating a production process which consists of various links, in the form of different suppliers, consumers and markets located in different regions of the world, enlarges transaction costs. Exploiting all advantages of specialization and fragmentation as good as possible requires excellent *transaction management* which aims at minimizing transaction costs, enhancing trade and making existing trade more profitable.

The concept of transaction management is clarified by taking a swift look at the Ricardian theory of *comparative advantage*. David Ricardo explained goods and service trade flows from comparative advantages that countries have. The theory of comparative advantage states that a country has a comparative advantage if it is relatively well-endowed with an input that is intensively used in the production of a product. An important assumption of this classic theory is that the production process is integrated within just *one* country. This assumptions does not hold anymore in the current pattern of production were most of the production processes are segmented and spread over an international network of production sites. According to Baldone *et al.* (2007) it is likely that an *absolute cost advantage* or a *specific combination of the phases of production* - taking place in various international locations - creates an advantage in world markets and originates a trade flow. Good transaction management, aimed at lowering transaction costs, could give rise to this cost advantage or specific combination of production phases. In this context Den Butter (2011) defines transaction management as *''the ability to keep the costs of trade transactions as low as possible so that the value creation from these transactions is optimized.''*

Grossman and Rossi-Hansberg (2008) have a similar view on trade as Baldone *et al.* (2007), in their opinion trade does not entail an exchange of goods anymore, it increasingly involves bits of value being added in many different locations, or what might be called *trade in tasks.* According to their theory it is not a comparative advantage in the production of goods or services but one in performing tasks that is the determinant of international trade flows. This suggests that a country could have a comparative advantage in performing profitable transactions, i.e. a comparative advantage in transaction management (Den Butter

2010). A country can preserve this comparative advantage by trade innovation which lowers transaction costs (Baeten and Den Butter 2006). It is not the goal of this paper to intensively discuss the theoretical aspects of trade innovation as a general definition serves the purpose of empirically estimating the effect of trade innovation on productivity.

ii. Transaction Costs

The previous paragraph discussed the concept of transaction management, which was defined as the ability to connect the various chains in a production process while keeping transaction costs as low as possible. Cheung (1987) provides the most elementary definition of transaction costs by defining them as "*all costs that do not occur in a 'Robinson Crusoe' economy where neither property rights, nor transactions, nor any kind of economic organization can be found*". In analogy of Cheung's reasoning: every transaction in our current economic system – which is characterized by the absence of direct exchange of goods - involves costs. Thus, transaction costs can be viewed as costs of participating in a market. Ronald Coase has stood at the basis of this basic view on transaction costs, even though he didn't define these costs explicitly as transaction costs in his famous work "The Nature of The Firm". According to Coase (1937) the *cost of using the price mechanism* is a reason why it is profitable to establish a firm. Coase assumed that the *operation of a market costs something* and by *allowing a firm to direct the resources, saves certain costs.* Hence, firms originate because of the existence of transaction costs. The importance of transaction costs is emphasized by Williamson (1979) who states that ''*if transaction costs would be negligible, the organization of economic activity would be irrelevant as the advantages of organizing would be eliminated by costless contracting*.'' Williamson (1985) elaborated the concept of transaction costs and focused on sources of the existence of transaction costs. Discussing what the sources of transaction cost are extends beyond the goal of this paper so is it neither practical nor desirable to focus on this part of the literature.

Firms make various costs in order to conduct business and perform transactions. A part of these costs concern production costs, i.e. primary costs of production. These costs can be defined as costs of material, labor and machines. The other part consists of costs which make production possible and conducting a business profitable; e.g. costs of hiring people, marketing costs, sales costs, costs of finding new markets and contract costs. All other costs, production costs excluded, are *transaction costs*. From that perspective Den Butter (2011) defines transaction cost as ''*the costs which are made in order to coordinate and connect all links in the production chain.*'' These costs can refer to costs internal to the organization but could also be external. Within firms, transaction costs relate to the costs of coordination that take place trough the hierarchy of the firm. Between firms, transaction costs take place via the market mechanism and relate to costs of outsourcing and trade. Wallis and North (1986) make a corresponding distinction between costs. According to them, costs can be divided in *transformation costs* and *transaction costs*. Transformation costs are all costs made associated with transforming inputs into outputs, while the latter are costs associated with making exchanges.

Various economists have tried to measure transaction costs. Wallis and North (1986) were the first to make an attempt. They measured transaction costs by measuring what they call the 'transaction sector'. By measuring the total value of resources used in the transaction sector, they came up with the aggregate size of transaction costs in the economy. Their findings emphasize the importance of transaction costs in the current global economy. They showed that the proportion of U.S. GNP in the transaction sector has grown from 25% in 1870 to 45% in 1970.

Unfortunately, there is a drawback to their estimate. In their analysis they make a distinction between occupations that provide primarily transaction services to the firm and those that provide primarily transformation services. The wages of employees in the *transaction occupations* embodies their measure of the transaction sector. However, it is difficult to make a distinction between these jobs as all jobs have elements of production and transaction in them. This makes it questionable whether their estimate is robust to changes.

In their survey on the measurement of trade costs Anderson and Van Wincoop (2004) illustrate trade costs by an ad valorem tax equivalent – from a theoretical point of view trade costs have the same discretional effect on product markets as taxes. In their opinion trade costs include all costs incurred in getting a good to a final user other than the marginal cost of producing the good itself (e.g. transport, border-related and local distribution costs). They arrive at an estimate of the tax equivalent of trade costs for industrialized countries of 170%. The number breaks down as follows: 21% transportation costs, 44% border related trade barriers and 55% retail and wholesale distribution costs. For developing countries this figure is even higher.

Transaction costs are very important in our current economic system and driving force behind this is the division of labor which is spurred by globalization. Wang (2003) states that as economies more and more integrate, the division of labor extends further and gives rise to more exchange and hence necessitating more resources to transactions. In order to benefit from this it is desirable to minimize transaction costs. Managing transactions and minimizing transaction costs can enhance trade and make existing trade more profitable, which in turn can foster growth. But how important is trade for economic growth? The next section discusses the link between trade and economic growth.

iii. Trade and Growth

Specialization and the division of labor have led to an evolvement of production processes and consist nowadays more of connecting all the channels of the production process with each other rather than producing all the components of a final product. As a result, more resources are necessitated to transactions and this has increased the importance of transaction costs and the ability to minimize them. Lower transaction costs will enhance trade and make existing trade more profitable and will on the short- and long-run be beneficial for economic growth. The relation between trade and economic growth has a bi-directional causality. Not only does trade stimulate economic growth, but improved technology and economic growth in turn are likely to create more trade (Van den Berg and Lewer 2006).

Lewer and Van Den Berg (2003) performed a survey of existing empirical literature that analyzed the effect of trade on growth. Their study focused on a large number of empirical studies that directly estimated the relation between international trade and economic growth. They find that all the analyzed papers are consistent in terms of the size of the relationship between trade and growth: a one percentage point increase in the growth of exports is associated with a one fifth percentage point increase in economic growth. Frankel and Romer (1999) analyzed the relation between trade and income and came to a comparable positive conclusion: trade raises income. To be more precise, they find that a rise of one percentage point in the ratio of trade to GDP increases income per person by at least one-half percent. Their main conclusion is that trade appears to raise income by spurring the accumulation of physical and human capital and by increasing output for given levels of capital.

The empirical evidence on the positive relationship between trade and economic growth suggests that countries that manage to increase their trade flows or make existing trade flows more profitable – this can be achieved by minimizing transaction costs – could benefit from higher economic growth. Countries can lower transaction costs by trade innovation which further promotes specialization and trade (Baeten and Den Butter 2006). However, innovation is generally associated with new products or efficient production processes that lead to productivity improvements. Though, trading nations – that have a comparative advantage in conducting profitable transactions – are more likely to benefit from trade innovation, which lowers transaction costs and increases trade, rather than from product or process innovation. A study by Bernard and Jensen (1999) showed that firms that enter foreign markets and export are relatively more productive than their non-exporting counterparts. Viewed on a country scale, this means that countries which are *innovative on trade,* and thus able to lower transaction costs and increase their trade level, are likely to increase their productivity and economic growth.

iv. Empricial Evidence on (Trade) Innovation and Growth

If there is one consensus in the economic field it is that technological change has contributed, and still contributes, substantially to economic growth. Solow (1956) induced technological change in his growth accounting model by treating technological change as an exogenous factor that is responsible for growth which cannot be attributed to real changes in capital or labour. In the past decades the model of Solow has been elaborated and endogenous growth models, which treat 'technological change' as endogenous, have been created. According to Romer (1990), a pioneer in modeling endogenous growth, technological innovation is created in the research and development sectors using human capital and existing knowledge stock and is then used in the production of final goods and leads to permanent increases in the growth rate of output.

Studies which analyze the effect of innovation on economic growth consist, in most of the cases, in testing the effect of a proxy for innovation, often a R&D variable, on productivity growth. In modern growth theory productivity improvements are measured by the increase of TFP, which stands for *total factor productivity* and forms the part in the increase of output which cannot be attributed to increases in labor or capital inputs. A large set of empirical studies have been conducted in order to identify the relationship between R&D, innovation and growth numerically for various countries, regions, sectors and firms. Cameron (1998) provides a study in which the empirical evidence on the link between innovation and economic growth is surveyed. His study considered a number of different measures of innovation, such as R&D spending, patenting, and innovation counts. The majority of the surveyed studies found a strong and enduring link between R&D capital and output: a 1% increase in the R&D capital stock was found to lead to a rise in output of between 0.05% and 0.1%.

Nevertheless, studies that analyzed the effect of technological innovation on growth also showed that there are other factors explaining economic growth better or with the same magnitude as technological innovation. Ulku (2007) performed a sophisticated empirical analysis on the relation between innovation and economic growth. As expected, the relation of innovation (for which patent stock was used as a proxy) and per capita GDP growth is positive and significant. However, also other factors seemed to have a significant and (greater) positive effect on growth of per capita GDP. Investments, trade liberalization and institutional quality are all important determinants of per capita income levels of countries. For example, the effect of trade liberalization on per capita GDP growth of OECD countries seemed to be twice as large as the effect of an increase in innovation. A studied performed on the micro level by Li et al (2007), who conducted research on the major sources of production improvement and innovation growth of Chinese enterprises, based on a cross-sectional firm level survey conducted by the World Bank in 2001, shows similar results. An increase in R&D expenditure (measured by the ratio of R&D personnel to total personnel) leads to an increase in innovation in all industries, however, other variables such as training and managers' education level, outsourcing and participating in production networks have a positive and significant effect on innovation and growth.

The fact that other factors explain productivity growth with the same (or higher) magnitude as R&D capital gives scope for conducting further research on the determinants of productivity growth. One of the ways to incorporate this is by analyzing the effect of trade innovation, which lowers transaction costs, on productivity. Lowering transaction costs increases productivity in two different ways. First, lower transaction costs means that more resources can be directed to other purposes and this could increase total output. Second, lower transaction costs could increase the size of trade, which allows for more specialization and thus higher productivity (Den Butter *et al.* 2008).

Trade innovation is difficult to measure and this is undoubtedly the reason for the lack of studies on the relation between trade innovation and growth. Den Butter *et al.* (2008) conducted a first attempt and tried to analyze the effect of trade innovation on productivity. They were fully aware of the difficult measurement problem of trade innovation and tried to overcome this by using the difference in the growth rate of trade and the growth rate of output as a proxy for trade innovation. They assumed that without trade innovation the costs of trading would not decrease and the growth of trade would be equal to the growth of output. In their study they tried to analyze how much trade innovation and R&D contributed to TFP in the Netherlands and whether trade innovation contributed more to TFP than investments in R&D. In their model the amount of trade can be seen as a function of trade innovation and demand. In order to bring the proxy of trade innovation in line with the stock of R&D, which is used as an indicator for product innovation, they created a stock variable for trade innovation by making an index with the base year 1950 based on the differences in the growth rates of trade and production. They find that trade innovation carried a larger weight than product and process innovation in determining TFP and that trade innovation has been more important than process and product innovation for productivity growth in the Netherlands. The next sections are devoted to the empirical analysis in which the effect of trade innovation on productivity is assessed for thirteen OECD-countries.

3. THE MODEL

This section is devoted to explaining the model that has been used to carry out the empirical analysis. As mentioned before, the effect of trade innovation on productivity is still unfathomed. Den Butter *et al.* (2008) performed a first attempt to quantify this relationship and their model forms the basis of this analysis.

The model that is used to conduct the empirical analysis builds on three assumptions: (1) total factor productivity is driven by innovation; (2) innovation consists of technological and trade innovation; (3) *export intensity* captures the effort on trade innovation and expenditures on *R&D* reflect technological innovation.

Apart from innovation, productivity can be affected by various other determinants; e.g. human and physical capital, infrastructure, privatization, competition and technological spillovers. The first assumption which states that productivity is driven by innovation is not meant to play down the effect of other possible determinants or to argue that innovation is the *only* source of productivity growth. Rather, this assumption is made in order to isolate the effect of innovation on productivity and thoroughly analyze the effect of trade innovation in particular. The second assumption is also made to serve the latter goal. The central question of this paper is to picture the effect of trade innovation on productivity. In order to answer that question it is necessary to make a distinction between technological and trade innovation which in reality is not so easy to make as trade and technological innovation are strongly linked to each other. As a result R&D figures could include trade innovation and vice versa. Therefore multicollinearity might exist. The third assumption is explained in more detail below. It is worth mentioning here that the proxy of trade innovation, unlike that of technological innovation, does not measure the *amount of resources* spend on trade innovation. Therefore nothing can be said about the effectiveness of these kinds of innovation (Den Butter *et al.* 2008).

In order to estimate the effect of technological and trade innovation on total factor productivity it is assumed that TFP is explained by R&D stock and trade innovation, for which export intensity is used as a proxy.[3] A vector of control variables is included in order to control for other determinants of productivity. The model is defined as:

$$TFP_{it} = \beta_0 + {RD_{it}}^{\beta_1} + {TI_{it}}^{\beta_2} + {Z_{it}}^{\delta} + \varepsilon_{it} \qquad [1]$$

where *TFP* represents total factor productivity, *RD* stands for technological innovation, *TI* reflects trade innovation, *Z* is a vector of control variables and the subscripts *i* and *t* stand for country respectively time.

The addition of a vector of control variables serves two purposes. The first is to quantify the effect of other determinants on productivity. Secondly, it allows to obtain more reliable estimates of the effect of the main explanatory variables (R&D stock and export intensity).

Three control variables are considered: *human capital*, *technological spillovers* and *openness*. The effect of human capital is controlled for by using the enrollment ratio to tertiary education as a proxy, the import share of high tech goods controls for the effect of technological spillovers and openness is controlled for by the trade-to-GDP ratio.

i. Technological Innovation

R&D expenditure – either aggregated, or broken down into components such as basic and applied, private or government - is commonly used as a proxy for product and process innovation in studies on the effect of innovation on growth. As R&D expenditure comprises all expenditure on research and development in business enterprises, government sector, higher education and non-profit firms it captures all national efforts on product and process innovation quite well and is therefore suited to proxy for technological

[3] This study uses data from the 2007 and 2009 EU-Klems databases for TFP. See section 4 for more information.

innovation. Studies by Globerman (1972), Griliches (1980), and Lichtenberg (1992) are examples of studies that used R&D spending as an explanatory variable of productivity growth.

To measure R&D stock I follow Den Butter *et al.* (2008) who use the perpetual inventory method (PIM). Expenditure on R&D is assumed to last for fifteen years and is then fully depreciated:

$$RD_{it} = \sum_{j=0}^{15} RE_{it-j} \qquad [2]$$

where *RD* stands for R&D stock, *RE* is R&D expenditure and *i* and *t* refer to country and time.

ii. Trade Innovation

Apparently there are no data on investments in knowledge which reduce transaction costs, not at the level of the firm or industry and even less so at the level of the aggregate economy. Therefore, in a macro-economic time series analysis only very crude proxies can be used for measuring trade innovation. Whereas Den Butter *et al*. (2008) use trade growth relative to production growth as an indicator, this study uses export intensity as a proxy for trade innovation. Export intensity, which is defined as the export of goods and services divided by total output, is a measure of a country's trade level. Over the years, the export intensity of some of the countries under examination here has increased sharply while for the others it showed hardly any movement.[4] In this perspective Bartelsman and Doms (2000) note that exporting can be related to productivity in several ways. First, only efficient firms who are highly productive are likely to overcome the obstacles of exporting and succeed in trading on world markets. Second, firms are by trading on world markets exposed to other firms and can learn about available technology and efficient ways of producing, which can increase their productivity. Third, exporting can increase the production scale of firms, which in turn makes them able to operate on a more-efficient scale and decrease their average cost curves.

[4] This is thoroughly depicted in section 5

The first link between productivity and export (only productive firms are able to export) is confirmed by diverse empirical studies. Bernard *et al.* (1995) used micro data from exporters and non-exporters in the US between 1976 and 1987 and showed that compared at a point in time, exporters exhibit better performance characteristics than non-exporters in every dimension; exporters are larger, more productive, and more capital intensive. This study seems to confirm the scale effect identified by Bartelsmans and Doms. Clederis *et al.* (1998) also shows that firms that become exporters typically have high productivity before they enter foreign markets. However, their relative efficiency does not systematically increase after foreign sales are initiated, which does not confirm the second relation between exporting and productivity, i.e. firms become more productive once they enter world markets and are exposed to other firms. In a study by Bernard and Jensen (1999), in which they addressed the question of whether exporters increase their productivity after entering foreign markets and whether firms that increase their productivity are more likely to export, they found that relatively productive firms are likely to export, yet they found little change in efficiency after exporting had begun. These results are comparable with those found by Cleridis *et al.*

Viewed on a country scale - if the micro findings would be converted to the macro level - only countries which are productive enough can overcome the obstacles of exporting and are able to trade on world markets. This would mean that a country can only increase its export intensity if it has become more productive.[5] This makes export intensity and its movement across time a good proxy for trade innovation as it captures the innovative efforts on trade. An increase in export intensity means that a country exports more of its output on the world market and that a country has been more and more *innovative on trade*.

Export intensity is defined as:

$$XI_{it} = \frac{EX_{it}}{TO_{it}} \quad [3]$$

[5] Obstacles such as import restrictions, exchange rate manipulation and so on are neglected in this view.

where *XI* stands for export intensity, *EX* stands for total exports of goods, *TO* for total output of all industries and *i* and *t* represent country respectively time.[6]

To measure trade innovation, growth of export intensity is used to create a 'stock' of trade innovation. Growth of export intensity is defined as the export intensity in a year divided by the level in the preceding year. This growth is then used to create a stock variable with 1980 as base year. The growth rate is defined as:

$$TI\ growth_{it} = \frac{XI_{it}}{XI_{it-1}} \quad [4]$$

where *TI growth* stands for growth in trade innovation, *XI* for export intensity and *i* and *t* are country and time.

iii. Control Variables

As mentioned above, productivity increases can have different determinants and in order to control for omitted variable bias and obtain more reliable estimates of the main explanatory variables, control variables are included in the model. The model controls for the effect of *human capital*, *technological spillovers* and *openness* on productivity.

Human Capital

There are several reasons to expect an effect of education on productivity. First, it seems very plausible that a link between the increased standards of living in the preceding 200 year and education exists (Stevens and Weale 2004). Another reason to expect an effect of education on productivity is because of the relation between education and science; the latter has been and still is an important contributor to technological progress, which in turn benefits economic growth. A third link between education and productivity is

[6] Expressing export intensity as a fraction mitigates the effect of inflation.

provided by Mankiw *et al.* (1992): education can increase the *human capital* in a labor force and as a result, productivity is increased and this can lead to a higher equilibrium level of output.

Various studies on the micro and macro level have been performed in order to analyze the effect of education on economic growth. Barro (2001) finds that growth is positively related to the average years of school attainment (of adult males) at the secondary and higher levels. This is confirmed by a study of Hua (2005) on the effect of education and productivity in a couple of Chinese provinces. He finds that university education has a favorable effect on efficiency growth (productivity growth).

The calculation of TFP from the EU Klems database already takes quality increases in the labor force into account so that in this empirical analysis the human capital variable represents the contribution of increases in disembodied knowledge to productivity. The gross ratio of enrollment in tertiary education is used to proxy for *disembodied human capital*. This ratio is measured as the ratio of total enrollment in tertiary education, regardless of age, to the population of the age group that officially corresponds to the level of tertiary education. The ratio is defined as:[7]

$$HC_{it} = \frac{TE_{it}}{AG_{it}} \qquad [5]$$

where *HC* stands for human capital, *TE* stands for tertiary education enrollment and *AG* for age group that officially corresponds to the level of tertiary education, *i* and *t* represent country and time.

TECHNOLOGICAL SPILLOVERS

Countries can use new technological knowledge from other countries to increase their productivity in two ways. First, they can import technologically more advanced products and higher quality goods to increase their labor productivity. Second, new technology from other countries can be used to produce new ideas or new applications in research & development. Technological spillovers have received much attention in

[7] This variable is provided by the UNESCO Institute for Statistics. See section 4.

economic research. Coe and Helpman (1995) were one of the first to study the effects of technological spillovers on productivity. In particular, they focused on R&D spillovers and found that technological spillovers are beneficial to a country's productivity and that open countries benefit more from this than less open economies. Madsen (2005), who conducted research on technological spillovers through trade, concluded that import of knowledge has been responsible for an almost 200% increase in TFP of OECD countries over the past century.

Highly technological products as a share of imports of all goods are used to proxy for technological spillovers. Since technological spillovers through imports are strongest for technologically sophisticated product imports, I follow Madsen (2005) and use the imports of products that are classified by the OECD as high technological such as machinery, equipment and chemical products.[8] Technological spillovers are calculated as:

$$TS_{it} = \frac{IMhigh_{it}}{IMall_{it}} \qquad [6]$$

where *TS* stands for technological spillovers, *IMhigh* stand for the import of products which are classified by the OECD as highly technological products, *IMall* stands for the imports of all goods and *i* and *t* refer to country and time.

Openness

Openness to international trade is seen as an important contributor to economic growth. Openness increases competition and the exposure to better and efficient ways of producing which can contribute to productivity growth. Sachs *et al.* (1995) have shown empirically that international openness is an important contributor to economic growth. This is supported by Abizadeh and Pandey (2009), who performed a panel data analysis of 20 OCED countries and found that trade openness has a positive impact of TFP growth for

[8] The high technological products are SITC Section 5, chemicals and related products, Section 7, machinery and transport equipment, and Section 8.7, professional and scientific instruments.

the aggregate economy.[9] The openness variable is calculated as the ratio of exports plus imports divided by GDP:[10]

$$OPEN_{it} = \frac{IM_{it} + EX_{it}}{GDP_{it}} \qquad [7]$$

where *OPEN* stands for openness, *IM* stands for imports of goods and services, *EX* stands for export of goods and services, *GDP* stands for itself, *i* and t represents country and time.

4. Data

Data consists of total factor productivity, gross R&D expenditure, exports of goods and services, imports of goods – both aggregated as well as split up in sections -, total output, total trade as a fraction of GDP and tertiary education enrollment ratios. Data is analyzed for thirteen OECD countries for the sample period 1980-2007.[11] All data is converted to yearly frequencies.[12]

Total factor productivity (TFP) and *total output* are obtained from the *EU KLEMS* 2009 database.[13] TFP data is included in the form of total productivity growth with 1995 as base year.[14] These growth rates have been used to calculate the level of TFP. Total output consists of a country's total output of all industries in a year. Figures are converted into U.S. Dollars by using the monthly average exchange rates from the *OECD MEI financial indicators* (database).

Gross R&D expenditure (GERD) data is obtained from the *OECD Main Statistics and Technology Indicators* (database) and is measured in U.S. Dollars. It is defined as total expenditure on R&D performed on national

[9] Abizadeh and Pandey (2009) use both the *traditional* as well as *real* openness and both yield similar results with respect to the effect of openness to productivity growth. Real openness is defined as total trade divided by, for purchasing power parity corrected, output.
[10] This variable is provided by Penn World Table 7. See section 4.
[11] These countries are: Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, United Kingdom and the United States. See section 5 for more information.
[12] Appendix 3 provides a table with the data sources and the original frequencies.
[13] For a summary overview of the methodology and construction of the EU KLEMS database, see: O'Mahony, Mary and Marcel P. Timmer (2009).
[14] For Canada the EU KLEMS 2007 database is used.

territory during a given period, which includes the R&D performed within a country and funded from abroad but excludes payments made abroad for R&D. It comprises of R&D expenditure in business enterprises, government sector, higher education and non-profit firms.

Imports and *exports* are obtained from the *OECD International Trade by Commodity Statistics* (database), measured using the UN guidelines and include all goods which add to or subtract from the stock of material resources of a country by entering (as imports) or leaving (as exports) its economic territory. Measurement is in U.S. Dollars and figures are obtained by converting the figures expressed in national currency using the monthly average exchange rate. Imports classified by sections of SITC 5, 7, and 8.7 are obtained from the OECD *Monthly Statistics of International Trade* (database).

Data on the gross enrollment ratio in tertiary education is obtained from education statistics database of the *UNESCO Institute for Statistics* . The openness variable is obtained from the *Penn World Table* (PWT7).

Data on total factor productivity and export of services is interpolated or extrapolated when not available by using the average growth rate of the five preceding or succeeding years.[15]

5. Statistical Analysis of Data

This section examines the statistical properties of the data and presents some stylized facts about the main variables of the model: TFP, export intensity and R&D.[16] The empirical analysis is conducted for thirteen OECD-countries. In order to analyze whether the effect of technological and trade innovation differs between countries, the countries are divided into groups (Table 1). Countries with high (low) aggregate GDP are in the *large* (*small*) *market* group. Countries with a trade-to-GDP ratio of more (less) than 1 are in the *trade-oriented* (*production-oriented*) group.

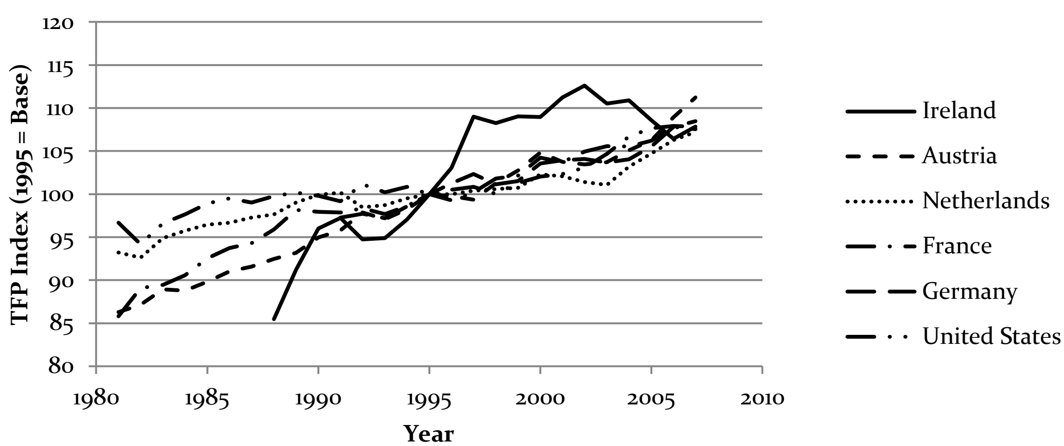
[15] TFP data for Canada for 2005, 2006 and 2007 is extrapolated. For Germany data on TFP has been interpolated for the period 1981-1990. For Ireland TFP has been interpolated for the period 1981 – 1987. For all countries data on the export of services is interpolated for the period 1981 – 1989. For Austria and France this period is 1981 -1994. For Sweden it is 1981 – 1991.
[16] Graphs of TFP, export intensity and R&D on the individual country level are shown in Appendix 2. Descriptive statistics are summarized in Appendix 3; Table D.

TABLE 1 LIST OF THE COUNTRIES IN EACH SAMPLE

Full Sample	Large Market	Small Market	Trade-oriented	Production-oriented
Austria	Canada	Austria	Austria	Canada
Canada	France	Denmark	Denmark	Finland
Denmark	Germany	Finland	Ireland	France
Finland	Italy	Ireland	Netherlands	Germany
France	Spain	Netherlands		Italy
Germany	United Kingdom	Sweden		Spain
Ireland	United States			Sweden
Italy				United Kingdom
Netherlands				United States
Spain				
Sweden				
United Kingdom				
United States				

The movement of TFP is depicted in Figure 1. Total factor productivity in the period 1980 – 2007 increased in all countries. However, the upward trend was neither uniform among countries and across time.[17] The movement of TFP shows fluctuations in all countries and some countries managed to increase their productivity relatively more than others. Over the reported period, the United States increased productivity with 9 %, while Ireland increased total factor productivity with 26% in an even shorter period (1988-2007).

FIGURE 1 *TFP INDEX,* 1981 – 2007

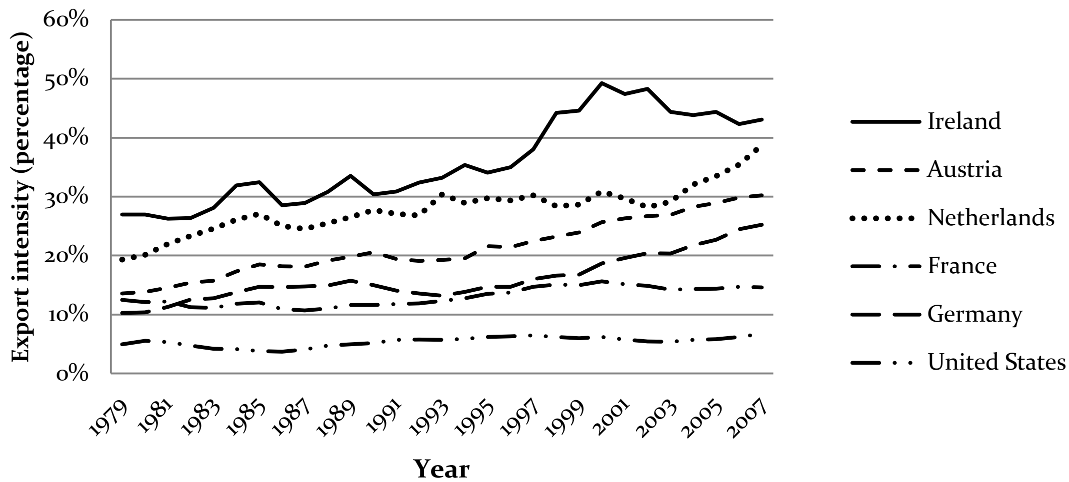


Source: EU KLEMS 2009 Database

[17] Countries which are not shown in Figure 1 show similar or in between values.

The movement of export intensity shows a similar pattern as TFP. Figure 2 shows that the trend for most of the countries was upward; however, the magnitude of growth differed substantially between countries and time.[18] Small countries, e.g. Ireland and the Netherlands, have experienced a larger growth in their export intensity than large countries, e.g. France and the United States. Furthermore, the level of export intensity is considerably higher for small countries.

FIGURE 2 *EXPORT INTENSITY*, 1979 – 2007



Sources: Exports goods and services (OECD), total output (EU KLEMS 2009 and 2007 database).
Note: Export Intensity is defined as the fraction of exports of goods and services in total output.

The difference in the growth rate of export intensity could for a part be explained by the large internal trade flows of large countries which substitutes for a part for the large external trade flows of small countries. Small countries are much sooner forced to carry out a part of their commerce to foreign countries while large countries can exercise this on the national level. Another possible explanation could be government policy which stimulates export, or favorable changes in terms of trade. It is not the goal of this study to explain the movement of export intensity over time. However, the fact that the movement over time shows some similarities with the movement of TFP strengthens the support for using export intensity as an explanatory variable in [1].

[18] Countries which are not shown in Figure 2 show similar or in between values.

Table 2 documents the ranking of the countries in terms of their aggregate and per capita R&D expenditure and R&D expenditure as a fraction of GDP. As seen from Table 2, large market countries are in the highest rank as far as aggregate R&D expenditure is concerned. When assessing R&D expenditure per capita and as a fraction of GDP, small market countries perform better and only the U.S. is still in the highest rank. The high R&D expenditure values of large market countries suggest that technological innovation could be a strong determinant of their productivity increases. This suggestion is fostered by the strong correlation between R&D stock and TFP, which is depicted in Table 3. On the other hand, small countries have strong correlation coefficients between export intensity and TFP. This raises the idea that small countries foster their productivity by trade innovation.

TABLE 2 *RANKING OF COUNTRIES BY AGGREGATE R&D EXPENDITURE, R&D EXPENDITURE AS A FRACTION OF GDP AND PER CAPITA R&D EXPENDITURE*, 2007

Rank	**R&D Expenditure**	$ mln.	**R&D Expenditure as a fraction of GDP**	%	**Per Capita R&D Expenditure**	$ mln.
1	United States	373,185	Finland	3.47	Sweden	1,307
2	Germany	74,072	Sweden	3.40	Finland	1,256
3	France	44,045	United States	2.67	United States	1,236
4	United Kingdom	38,760	Denmark	2.58	Denmark	973
5	Canada	24,087	Germany	2.53	Austria	954
6	Italy	22,332	Austria	2.52	Germany	900
7	Spain	18,329	France	2.07	Canada	750
8	Netherlands	12,070	Canada	1.96	Netherlands	737
9	Sweden	11,961	Netherlands	1.81	France	691
10	Austria	7,923	United Kingdom	1.78	United Kingdom	636
11	Finland	6,642	Ireland	1.29	Ireland	582
12	Denmark	5,315	Spain	1.27	Spain	408
13	Ireland	2,542	Italy	1.18	Italy	376

Source: OECD

The presence of unit root in the data is tested by means of the Levin-Lin-Chu panel data unit root test (Levin *et al.* 2002) because individual unit root tests have limited power.[19] Results are shown in Table 4. The power of a test is the probability of rejecting the null when it is false and the null hypothesis is unit root. The Levin-Lin-Chu test is based on the null hypothesis that all cross sections have a unit root, which is very restrictive. The other disadvantage is that the test statistic relies critically on the assumption of cross-

[19] All the statistical tests carried out in this chapter are explained in more detail in Appendix 1

sectional independence. The test shows that TFP, R&D and the control variables exhibit unit root.[20] On the other hand, the Nyblom-Harvey (Nyblom and Harvey 2000) test shows that the variables do not share common trends are not co-integrated (Table 4). The Nyblom-Harvey test tests the validity of a specified value of the rank of the covariance matrix of the disturbances driving the multivariate random walk.[21] The special case calculated by this test is that of the rank equaling zero. The null is zero common trends and a failure to reject that hypothesis means that the data is not co-integrated.

TABLE 3 *CORRELATION BETWEEN TOTAL FACTOR PRODUCTIVITY, EXPORT INTENSITY AND R&D STOCK,* 1981 - 2007

Country	Correlation Export Intensity and TFP	Correlation R&D and TFP
Austria	0.9614	0.9524
Canada	0.6937	0.9857
Denmark	0.5157	0.5252
Finland	0.7633	0.9758
France	0.7675	0.9549
Germany	0.9046	0.9873
Ireland	0.8801	0.7851
Italy	-0.7815	0.7771
Netherlands	0.9342	0.9376
Spain	-0.4473	-0.5889
Sweden	0.8674	0.9895
United Kingdom	0.5119	0.9266
United States	0.5324	0.9371

TABLE 4 *LEVIN-LIN-CHU PANEL DATA UNIT ROOT* AND *NYBLOM-HARVEY PANEL DATA COINTEGRATION TEST, 1981 - 2007*

	Full Sample*		
	*Levin-Lin-Chu***		*Nyblom-Harvey*+
	t-star	p>t***	
TFP	0.21075	0.5835	4.1868
R&D	7.45696	1.0000	4.2376
Export Intensity	-1.83591	0.0332	4.1798
Openness	-1.60158	0.0546	4.1882
Import share of high tech goods	1.64645	0.9502	3.1560
Enrollment ratio	0.16771	0.5666	4.1893

All variables are in natural logs.
*/ regressions are augmented by one lag and none of them include a constant
**/ t-star statistics is distributed as standard normal under the null hypothesis of non-stationarity.
***/ unit root exists if p-value is higher than 0.05
+ critical value is 4,4957 at the five percent level

Sources: TFP, total output (EU Klems), R&D, export, import of high tech goods (OECD), enrollment ratio in tertiary education (UNCTAD), openness (PWT 7).

[20] According Levin *et al.* (2002) the test performs well when N (number of series) lies between 10 and 250, thus the test is performed for the full sample only as the other samples contain a less number of series.
[21] This rank is equal to the number of common trends, or levels, in the series.

Autocorrelation and heteroscedasticity are tested by performing the Breusch-Godfrey and White's general test for heteroscedasticity (Table 5). If the residuals of the models are serially correlated, heteroscedastic or both, it will not result in biased parameter estimates. However, the standard errors will be biased and this leads to bias in test statistics and confidence intervals. The data seems not to (for most countries) exhibit first order autocorrelation or heteroscedasticity.

TABLE 5 *AUTOCORRELATION AND HETEROSCEDASTICITY TEST,* 1981 -2007*

Country	Breusch-Godfrey (χ^2prob.)	White's general test for heteroscedasticity (χ^2prob.)
Austria	0.2284	0.3946
Canada	0.8063	0.5226
Denmark	0.1070	0.3946
Finland	0.0379	0.3946
France	0.2060	0.3946
Germany	0.0114	0.1852
Ireland	0.2066	0.3946
Italy	0.0265	0.3946
Netherlands	0.5139	0.3946
Spain	0.0389	0.3946
Sweden	0.4301	0.3946
United Kingdom	0.0950	0.3946
United States	0.6137	0.3946

*/ The heteroskedasticity test is applied to the predicted values of TFP, which are obtained from following the regression equation:

$$ln(TFP_{it}) = \beta_0 + \beta_1 ln(RD_{it}) + \beta_2 ln(TI_{it}) + \beta_3 ln(HC_{it}) + \beta_4 ln(TS_{it}) + \beta_5 ln(OPEN_{it}) + \varepsilon_{it}$$

For Canada and Germany the tests are applied to the predicted values of the above regression without education (EDU) as data on this explanatory variable was not available.
Values below 0.05 suggest the presence of heteroscedasticity or autocorrelation.

6. Empirical Analysis

A panel data approach is used to study the effect of trade and technological innovation on productivity. Islam (1995) has advocated the use of panel data to perform growth analysis as it allows for differences in the aggregate production function across economies and leads to results that significantly differ from single cross country regressions. Panel data provide a large number of data points and thus more degrees of freedom and variability (Baltagi 2005). Second, panel data reduces collinearity among explanatory variables

(Hsiao 2003) and third, as Balgati (2005) argues, panel data gives the possibility to control for individual heterogeneity. This is very important as it enables the control for variables which cannot be observed or measured over time but could be correlated with the variables used in the analysis.

The previous chapter showed some interesting insights: total factor productivity has had an upward trend for all countries but the magnitude differed among them; small market and trade-oriented countries exhibit a strong correlation between export intensity and TFP; export intensity has had a strong upward trend for the small market and trade-oriented countries and large market countries exhibit a stronger correlation between R&D and TFP, and are ranked high in R&D expenditure. Based on these observations and the assumptions of the model (discussed in chapter 3) the following two hypotheses are assessed:

> Hypothesis I: *trade innovation is an important explanatory variable of total factor productivity.*
>
> Hypothesis II: *for trade-oriented countries, trade innovation explains total factor productivity better than technological innovation and vice versa for production-oriented countries.*

The fixed effects model is used to analyze the effect of trade and technological innovation on productivity.[22] The models which are estimated in the next section do not make use of the lagged dependent variable as including this variable leads to an upward bias of its effect and a downward bias of the effect of the other explanatory variables (Hsiao 2003). The presence of unit root in TFP and R&D is neglected as explaining TFP by the level of trade innovation and differencing the data of TFP, R&D and the control variables would not have any economic interpretation.

i. Basic Results

The first model that is estimated is a model without any control variables. Hence, only trade and technological innovation are used as explanatory variables of TFP:

[22] A hausman test has been performed in order to choose between the random effects or fixed effects model. The χ^2 probability is 0.0001 and leads to a rejection of the null hypothesis that the random effects model is preferred above the fixed effects model (critical value: 0.05)

$$ln(\text{TFP}_{\text{it}}) = \beta_0 + \beta_1 ln(\text{R}D_{it}) + \beta_2 ln(\text{TI}_{it}) + \varepsilon_{it} \quad [8]$$

In this model natural logarithms are taken in order to allow for an elasticity interpretation. The purposes of estimating the model without controlling for other variables enables us to examine solely the effect of innovation on productivity. These obtained results can later on be compared to those of the model with control variables in order to assess whether controlling for human capital, technological spillovers and openness yields more reliable results.

Table 6 shows that trade innovation, which lowers transaction costs, increases trade and makes existing trade more profitable, has had a beneficial effect on total factor productivity in the period 1981-2007. Thus, the first hypothesis which states that trade innovation is an important explanatory variable of total factor productivity cannot be rejected. The coefficient value in the full sample of trade innovation (0.14) is almost three times larger than that of R&D (0.05), which is used as a proxy for technological innovation, indicating that trade innovation is indeed an important determinant of productivity.[23]

The estimated results also affirm the second hypothesis. The elasticity between R&D and productivity for production-oriented countries is more than three times higher than the elasticity between trade innovation and productivity. This long-run effect of technological innovation (0.11) is in accordance with a survey by Cameron (1998) who shows that most empirical studies find elasticities between R&D capital and output in the range of 0.06 to 0.42. In contrast, the effect of R&D on productivity for trade-oriented countries is much lower (0.04). While the high elasticity of trade innovation (about 0.15) for this group suggests that in the examined period trade-oriented countries increased their productivity by being *innovative on trade*. This finding is consistent with the analysis of Den Butter *et al.* (2008) who find that trade innovation carried a large weight in determining TFP for the Netherlands in the period 1950 - 1992.

The coefficients of the large and small market group suggest that market size is *not* important in explaining the effect of trade and technological innovation on productivity. The high coefficient for trade innovation

[23] Both coefficients are significant at the 1% level.

suggests that for large market countries technological innovation is less important in determining productivity than trade innovation. At the same time, for small market countries it seems that technological innovation is more important in fostering productivity. This result can be explained by taking a closer look at the ranking in Table 2. The expectation was that high absolute value of R&D expenditure meant that countries foster their productivity by technological rather than trade innovation. This expectation is negated. Not the *absolute* but the *relative* expenditure on R&D is important. Countries like Finland and Sweden, who hold the top two positions in the R&D-to-GDP-ratio and the R&D expenditure per capita ranking, are included in the small market panel. While countries that have a large market like Spain, Italy and the UK are ranked in the bottom four positions in the previous mentioned rankings. This explains the results of the obtained coefficients in the large and small market groups.

TABLE 6 *FIXED EFFECT REGRESSION OF TOTAL FACTOR PRODUCTIVITY (EXCLUDING CONTROL VARIABLES), 1981 - 2007*

	Full Sample	**Large Market**	**Small Market**	**Trade-oriented**	**Production-oriented**
RD	0.0472***	0.0485***	0.0933***	0.0429***	0.1096***
	(0.004)	(0.006)	(0.009)	(0.012)	(0.008)
TI	0.1354***	0.124***	0.0721*	0.1505**	0.0256⁺
	(0.029)	(0.045)	(0.038)	(0.059)	(0.034)
Intercept	4.0513***	3.9976***	3.6485***	4.1175***	3.3067***
	(0.041)	(0.072)	(0.082)	(0.103)	(0.089)
Number of observations	351	189	162	108	243
Period	1981-2007	1981-2007	1981-2007	1981-2007	1981-2007
R^2	0.5322	0.4023	0.7506	0.6828	0.5968

Standard errors are reported in parenthesis. Statistical significance levels at 10%, 5% and 1% are indicated by *, ** and ***
⁺ t-value is 0.75

In summary, the basic regression results show that trade innovation is indeed an important determinant of productivity and has been beneficiary for the productivity level of trade-oriented countries. While in comparison, production-oriented countries have spurred their productivity by investing in R&D (technological innovation). Furthermore, the analysis showed an interesting insight in the relation between market size and R&D. Market size seems not to be important in explaining the effect of technological innovation on productivity as the effect of R&D on productivity does not depend on the absolute value of R&D expenditure but on the relative value.

However, the obtained results should be interpreted with caution because of the difficulty to disentangle technological and trade innovation and the possible existence of reverse causality between total factor productivity and innovation.

In order to examine the sensitivity of the obtained results with respect to changes in the proxy for trade innovation equation 8 is also estimated with openness (defined as exports plus imports divided by GDP) as a proxy for trade innovation. This estimation yielded similar results (see appendix 3; Table A). Furthermore, in order to analyze whether causality actually runs from technological and trade innovation to productivity a two-stage least squares estimation is conducted. Here, the lagged independent variables of equation 8 have been used as instruments. The results confirm that causality runs from innovation to TFP (see appendix 3; Table B).

ii. Controlling for Human Capital, Technological Spillovers and Openness

In order to examine the reliability of the estimates of the first model, the model is estimated again by including control variables. Table 7 depicts the results of the following estimated models:[24]

$$ln(\mathrm{TFP_{it}}) = \beta_0 + \beta_1 ln(\mathrm{R}D_{it}) + \beta_2 ln(\mathrm{TI}_{it}) + \beta_3 ln(HC_{it}) + \varepsilon_{it} \qquad [9]$$

$$ln(\mathrm{TFP_{it}}) = \beta_0 + \beta_1 ln(\mathrm{R}D_{it}) + \beta_2 ln(\mathrm{TI}_{it}) + \beta_3 ln(TS_{it}) + \varepsilon_{it} \qquad [10]$$

[24] Table C in Appendix 3 provides a table with the results of the model in which all the control variables are included:

$$ln(TFP_{it}) = \beta_0 + \beta_1 ln(RD_{it}) + \beta_2 ln(TI_{it}) + \beta_3 ln(HC_{it}) + \beta_4 ln(TS_{it}) + \beta_5 ln(OPEN_{it}) + \varepsilon_{it}$$

I preferred here to add the control variables one by one as this gives better and more reliable information.

$$ln(\text{TFP}_{\text{it}}) = \beta_0 + \beta_1 ln(\text{R}D_{it}) + \beta_2 ln(\text{TI}_{it}) + \beta_3 ln(OPEN_{it}) + \varepsilon_{it} \qquad [11]$$

Human capital seems to have a positive influence on productivity on the long-run as its coefficient is positive and significant in the full sample.[25] Although the effect of trade innovation in the full sample decreases from 0.14 to 0.08 it is still twice as large as the effect of human capital and R&D, which both have a coefficient of 0.03. Thus, adding the education variable does not alter the conclusion based on the basic regression results which showed that trade innovation is an important determinant of productivity. However, the effect of trade innovation decreases substantially which indicates that adding human capital as control variable provides more reliable estimates.

The effect of human capital differs between the different subsamples. Human capital seems to be more important for large market and production-oriented countries than for small market and trade-oriented countries. However, only the coefficient of the production-oriented sample is statistically significant. The estimated model suggests that R&D and human capital are strongly linked with each other as the importance of R&D decreases in the production-oriented sample when adding human capital as an explanatory variable.[26] This is in line with the finding of Engelbrecht (1997) who finds that the effect of domestic R&D is reduced when human capital is included.

Trade-oriented countries appear to increase their productivity by technological spillovers. The elasticity between technological spillovers and productivity is about 0.04.[27] This is not very surprising as trade-oriented countries are more open and are therefore more able to use foreign technological development to increase their productivity. Large market and production-oriented countries do not seem to increase their productivity by technological spillovers as the coefficients have negative values. This finding coincides for a part with that of Coe and Helpman (1995), although they find positive but rather small (on average less than 0.01) effects of technological spillovers on productivity for G-7 countries. Again, adding technological

[25] The human capital variable (HC) is significant in the full and production-oriented sample; for the other sub-samples, the coefficient seems less relevant. In all models (except the small market) the coefficient is positive.
[26] This applies also for the full, large market and trade-oriented samples.
[27] The coefficient for trade-oriented countries is significant at the 1 % level.

spillovers as a control variable does not harm the conclusion based on the basic specification [8]. Trade and technological innovation still have a positive and significant effect on productivity.[28]

The effect of trade innovation evaporates when adding openness as a control variable. Although the effect of trade innovation is still positive in the full sample, it is not significant anymore. Trade innovation seems not to be an important determinant for trade-oriented and small market countries while it becomes important for explaining productivity of large countries and production-oriented countries. On the other hand, openness seems to be very important for small market and production-oriented countries. Probably the way the openness variable is calculated (total imports and exports divided by GDP) causes a multicollinearity problem with the proxy for trade innovation, i.e. export intensity, and leads to indistinct results.

Summarizing, the regression results of regression 8 still hold when adding control variables. Adding control variables reduces the omitted variable bias and improves the reliability of the results of the basic regression. The results show that human capital has a positive and significant effect on total factor productivity. However, the effect differs between different subsamples. Technological spillovers are more important for open than for closed economies. Both findings coincide with results of other studies on human capital and technological spillovers. Including control variables does not harm the conclusion that trade innovation is an important determinant of productivity and improves the reliability of the estimated effect in [8].

[28] The coefficient for trade innovation yields a non-significant value for the full sample and the large market sample.

TABLE 7 *FIXED EFFECT REGRESSION OF TOTAL FACTOR PRODUCTIVITY (INCLUDING CONTROL VARIABLES), 1981 – 2007*[+]

	Full Sample	**Large Market**	**Small Market**	**Trade-oriented**	**Production-oriented**
			Specification 9[#]		
RD	0.0325***	0.0263***	0.1126***	0.0427***	0.02842 ***
	(0.005)	(0.005)	(0.019)	(0.012)	(0.011)
TI	0.0845***	-0.0481*	0.0811**	0.1495**	-0.0039
	(0.023)	(0.025)	(0.039)	(0.063)	(0.025)
HC	0.0333***	0.0243	-0.0415	0.0016	0.0828***
	(0.017)	(0.017)	(0.035)	(0.043)	(0.018)
Intercept	4.0998*	4.1751***	3.6133***	4.1149***	3.9409 ***
	(.0349375)	(0.036)	(0.087)	(0.098)	(0.076)
Number of observations	297	135	162	108	189
Period	1981-2007	1981-2007	1981-2007	1981-2007	1981-2007
R^2	0.6382	0.5340	0.7529	0.6828	0.5958
			Specification 10		
RD	0.0532***	0.0433***	0.0640***	0.0469***	0.0443 ***
	(0.009)	(.0102444)	(0.012)	(0.011)	(0.014)
TI	0.0529	0.0445	0.1152***	0.1319***	0.0785 **
	(0.0368)	(0.037)	(0.039)	(0.046)	(0.038)
TS	-0.1049***	-0.3611***	0.0028	0.0376***	-0.2291***
	(0.015)	(0.023)	(0.012)	(0.013)	(0.020)
Intercept	3.9138	3.8049***	3.9359***	4.1295	3.9048 ***
	(0.104)	(0.123)	(0.111)	(0.095)	(0.155)
Number of observations	260	140	120	80	180
Period	1988-2007	1988-2007	1988-2007	1988-2007	1988-2007
R^2	0.5152	0.7497	0.7312	0.7017	0.6736
			Specification 11		
RD	0.0451***	0.049***	0.0886***	0.0588***	0.1280***
	(0.004)	(0.007)	(0.009)	(0.008)	(0.009)
TI	0.0581	0.1405**	-0.0582	-0.2558***	0.1728***
	(0.047)	(0.072)	(0.055)	(0.092)	(0.053)
OPEN	0.0975**	-0.0217	0.1665***	0.3892***	-0.2093***
	(0.047)	(0.075)	(0.053)	(0.074)	(0.058)
Intercept	3.6866***	4.0689***	2.9893***	2.3217***	3.8946 ***
	(0.179)	(0.256)	(0.224)	(0.347)	(0.185)
Number of observations	351	189	162	108	243
Period	1981-2007	1981-2007	1981-2007	1981-2007	1981-2007
R^2	0.5382	0.4026	0.7658	0.7507	0.6181

Standard errors are reported in parenthesis. Statistical significance levels at 10%, 5% and 1% are indicated by *, ** and ***

[+] Specification 10 is estimated for the period 1988 – 2007 because of lack on data on high tech goods.

[#] Canada and Germany are not included because of the unavailability of data on tertiary education.

7. Conclusion

This section summarizes the main findings of this study, provides conclusions and policy implications, and indicates where future research should focus on.

Main Findings

This paper has analyzed the effect of trade and technological innovation on productivity. The innovation debate is dominated by the conception that efforts on research and development (R&D) yield positive benefits for society in the form of economic growth. The European Union (EU) formulated the ambition in the Lisbon Strategy in 2000 to become the "*most competitive and the most dynamic knowledge based economy in the world*" by 2010. This goal, which was supposed to be achieved by investing 3% of income on R&D, has yet to be accomplished. In our current economic system - in which transaction costs comprise a large part of economic activity – economic growth could also be fostered by further specialization and division of labor, which in turn is the result of innovation that lowers transaction costs – *trade innovation* - and enhances a country's trade level.

With the use of a panel data approach this study has tried to analyze the *importance of trade innovation for productivity of thirteen OECD countries* by focusing on i) the explanatory power of trade innovation in general and ii) the importance of trade innovation in fostering productivity for trade-oriented and production-oriented countries in particular. Export intensity has been used as a proxy for trade innovation and R&D expenditure served as a proxy for technological innovation. The empirical analysis has shown that trade innovation is indeed an important determinant of productivity. On the long-run, a 1% increase in trade innovation leads to an increase of productivity by 0.14%. The magnitude of technological innovation is 0.05%. These main findings are not altered by controlling for *human capital* and *technological spillovers,* although the magnitudes of the effects decrease.

For trade-oriented countries in particular, trade innovation appears to be very important: the long-run elasticity of innovation that lowers transaction costs is 0.15. This finding coincides with the analysis of Den Butter *et al*. (2008) in which a long-run elasticity of 0.20 is found for the Netherlands for the sub-period 1972-1992, a period that is comparable with the sample period of this analysis.

Technological innovation seems to be a better determinant of productivity of production-oriented countries (long-run elasticity is 0.11). This is in accordance with a large set of various international studies on the relationship between technological innovation and productivity that report an effect of about the same magnitude.

Furthermore, human capital seems to have a positive influence on productivity on the long-run for all countries, while small market and trade-oriented countries appear to increase their productivity by technological spillovers. It is not surprising that trade-oriented nations increase their productivity by technological spillovers as these countries are more open and trade more with foreign countries, which enables them to learn about available technology and efficient ways of producing. This corresponds with an influential study of Coe and Helpman (1995) in which they found that technological spillovers are more beneficial to the productivity of open economies.

A drawback of this study is that, as mentioned earlier, trade and technological innovation are strongly linked with each other. This makes it difficult to distinguish the different effects and thus their separate contribution to productivity. Furthermore, the proxy for trade innovation has a reverse causation with productivity. High export levels (intensity) can stimulate economic growth by inducing a relocation of factors across industries and firms leading to gains in production efficiency, on the aggregate level reflected in an increase of total factor productivity. While on the other hand, the causality could also run from productivity to export, i.e. being productive increases the opportunities for export.

The next two paragraphs discuss the impact that these findings have on future government policy and research.

Policy Implications

One must be careful in drawing policy conclusions from an exercise as such which is performed at an aggregate level and only focused on a period of 26 years. This paper has shown that productivity seems to be determined by technological as well as trade innovation. These conclusion advocates for a broad and coherent government policy on innovation. As a result I think that the one-size-fits-all approach as mapped out in the Lisbon Strategy, in which every country should invest 3% of income on research and development, is not justified. Rather, a policy which also incorporates trade innovation is warranted. More trade, spurred by innovation that lowers transaction costs, is beneficial via two channels. First, there is the direct channel of enhancing trade and thus higher growth. Second, technological spillovers, which become more available because of more trade, can also lead to productivity growth.

Furthermore, this paper suggests a positive policy implication with respect to investing in R&D. The finding that market size is not important in explaining the effect of technological innovation and that not the absolute but rather the *relative* efforts on R&D are important, gives scope for small countries to increase their productivity by means of investing in research and development. However, as mentioned earlier, this is not a justification of government policy to focus solely on R&D investments.

Future Research

The results in this study provide further insights in the directions of future research. First, the finding of a positive effect of trade innovation urges for more and sophisticated studies on this area. However, in order to be able to conduct that research a micro longitudinal data set on the plant level for various countries and sectors would be very beneficial. Second, this study tried to quantify a relationship which still does not receive its deserved attention. A study on the micro level could be conducive in answering: i) to what extent trade innovation contributes to productivity/output growth; and ii) the consequences of the increased role of transaction costs for the labor market. Third, although the proxy that has been used for trade innovation generated fruitful results it is still a rough measure and should be improved in future research.

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APPENDIX

1. Statistical Tests

This section describes the performed statistical tests in more detail. [29]

Levin-Lin-Chu Panel Data test

The test assumes that each individual unit in the panel shares the same AR(1) coefficient, but allows for individual effects, time effects and possibly a time trend. The null hypothesis is that each time series contains a unit root. The test work as follows – as explained by Levin, Lin and Chu (2002):

i. First an augmented Dickey-Fuller (ADF) is run for every cross-section on the equation:

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{L=1}^{\rho_i} \theta_{iL} \Delta y_{it-L} + \alpha_{mi} d_{mt} + \epsilon_{it}$$

Where y_{it} stands for the stochastic process for a panel of individuals, d_{mt} indicates the vector of deterministic variables, α_{mi} is the corresponding vector of coefficients for a particular model and ρ_i stands for the autoregressive order.

ii. Then two auxiliary are run in order to obtain and save the residuals $\widehat{e_{\iota t}}$ and $\widehat{v_{\iota t}}$:

$\widehat{e_{\iota t}}$ is obtained by running Δy_{it} on Δy_{it-L} and d_{mt}; and $\widehat{v_{\iota t}}$ is obtained by running $y_{i,t-1}$ on Δy_{it-L} and d_{mt}

iii. The residuals are then standardized by the standard error from each individual ADF.

iv. Finally the following pooled OLS regression is run: $\widetilde{e_{\iota t}} = \rho \widetilde{v_{\iota,t-1}} + \widetilde{\varepsilon_{\iota t}}$

The null hypothesis is $\rho = 0$, $\widetilde{e_{\iota t}}$ and $\widetilde{v_{\iota t}}$ are the standardized residuals. The obtained t-star statistic is distributed standard normal under the mentioned null hypothesis of nonstationarity.

[29] Although the tests are explained here in detail, they have not been performed manually but with the use of the statistical software package STATA

Nyblom-Harvey test for panel data cointegration

The Nyblom-Harvey test for co-integration tests for common trends where the null hypothesis is that there exists K < N common trends. Thus a failure to reject the null hypothesis of zero common trends is also an indication that the variables do not form a co-integrated combination. In Nyblom-Harvey terms K equals the rank of the covariance matrix of the disturbances driving the multivariate random walk. This rank is equal to the number of common trends, or levels, in the series. In their words *''when K is less than the number of series, N, the model contains K common random walk components or common trends. Common trends imply co-integration and vice versa.''* The advantage of using this test is that it is very simple and that it does not require any model to be estimated (Nyblom and Harvey 2000).

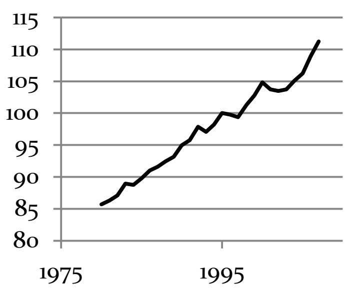
Autocorrelation and Heteroscedasticity

Autocorrelation and heteroscedasticity violate the ordinary least squares (OLS) assumptions that the error terms are uncorrelated and that it has an expected value of zero given any value of the independent variables (constant variance). Autocorrelation and Heteroscedasticity do not lead to biased coefficient estimates but cause biased standard errors. This in turn leads to bias in test statistics and confidence intervals and has a biased inference of the coefficients as a result. Autocorrelation and Heteroscedasticity are tested by the Breush-Godfrey respectively White's general test for heteroscedasticity. Both tests follow a Chi-square distribution (χ^2) under the null hypothesis of no autocorrelation (Breush-Godfrey) and of constant variance of the error term (White's general test for heteroscedasticity). The null hypotheses are rejected when the χ^2 probability is below 0.05.

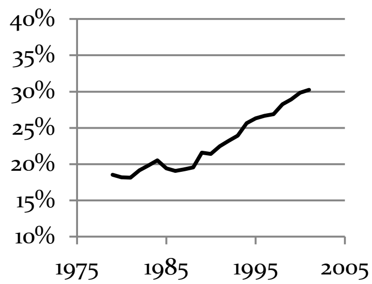
2. *TFP, Export Intensity and R&D on the country level*

Austria

TFP Index

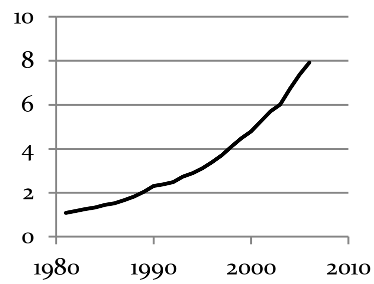


Export Intensity



R&D Expenditure

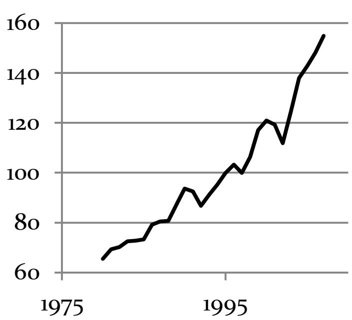
(Billion USD, current PPP)



Canada

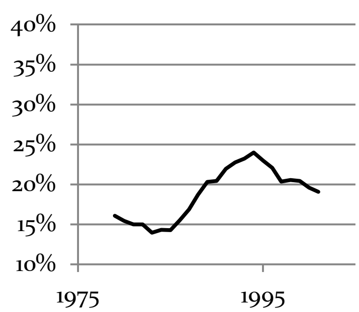
TFP Index

(1995 = base year)



Export Intensity

(Total Export/Total Output)



R&D Expenditure

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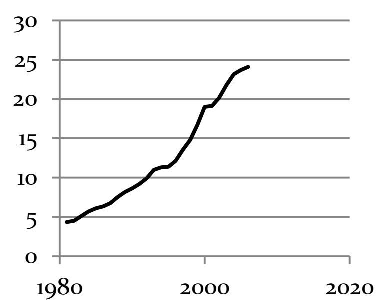
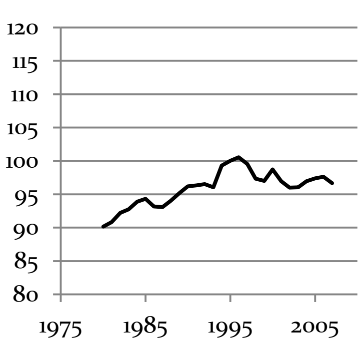


Denmark

TFP Index

(1995 = base year)



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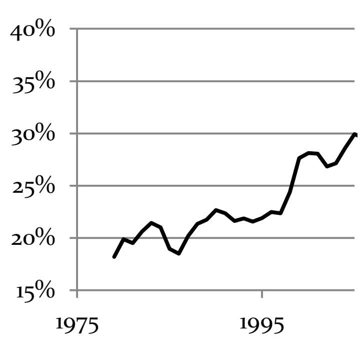

R&D Expenditure

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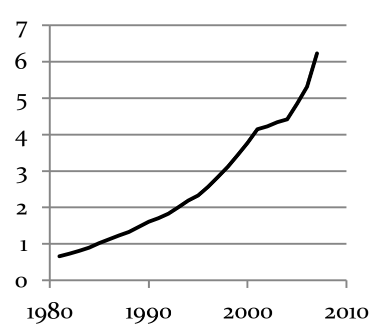

Finland

TFP Index

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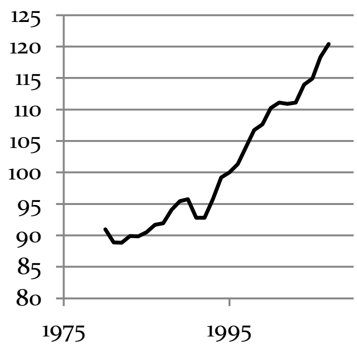

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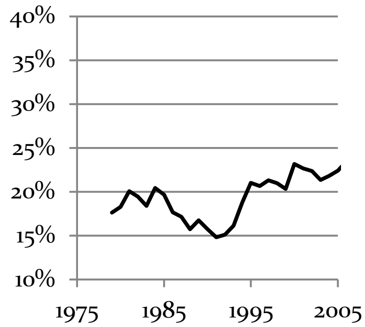

R&D Expenditure

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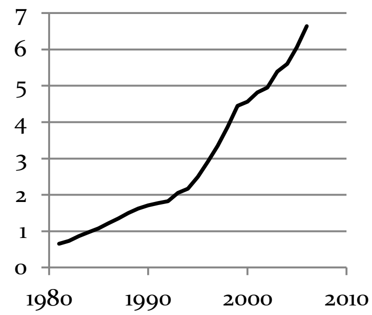
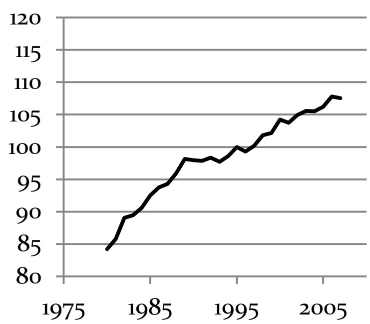


France

TFP Index

(1995 = base year)



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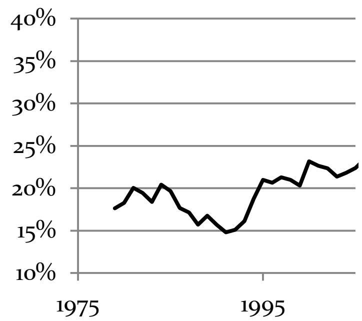

R&D Expenditure

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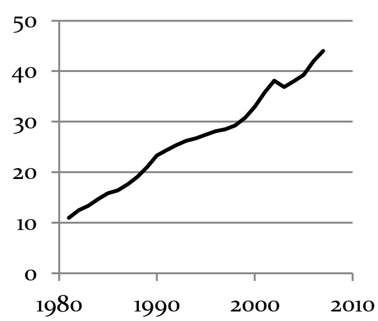
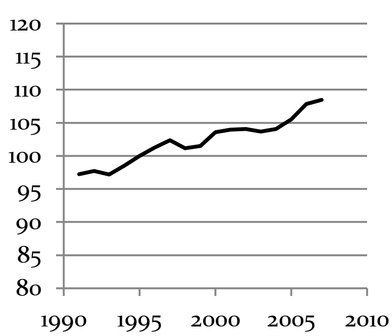


Germany

TFP Index

(1995 = base year)



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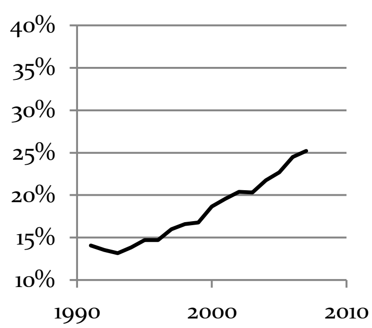

R&D Expenditure

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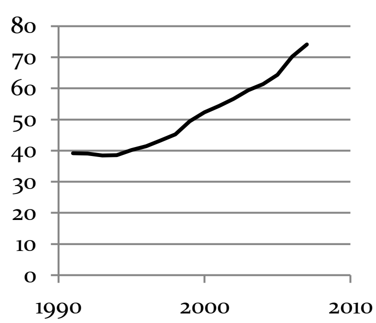

Ireland

TFP Index

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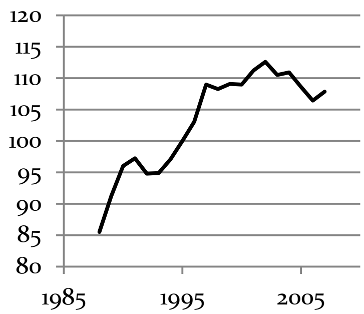

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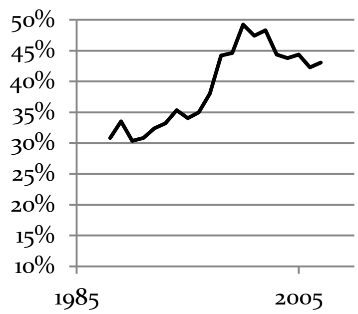

R&D Expenditure

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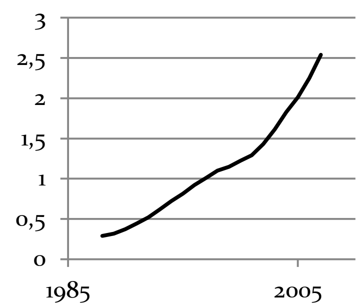
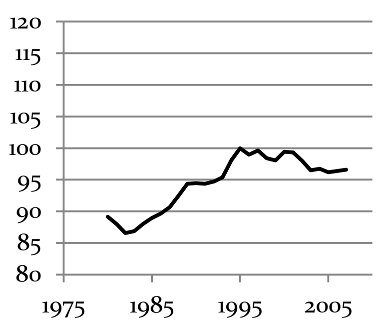


Italy

TFP Index

(1995 = base year)



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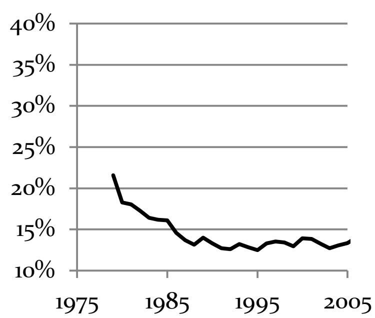

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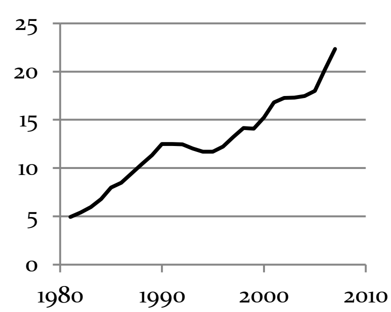
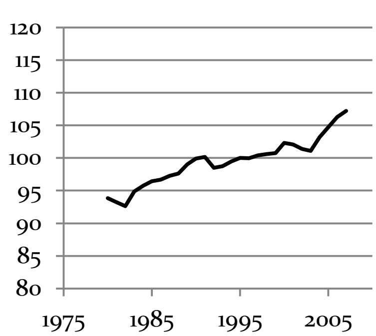


Netherlands

TFP Index

(1995 = base year)



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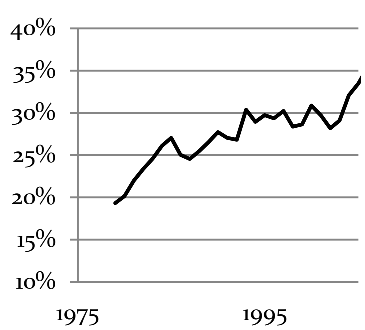

R&D Expenditure

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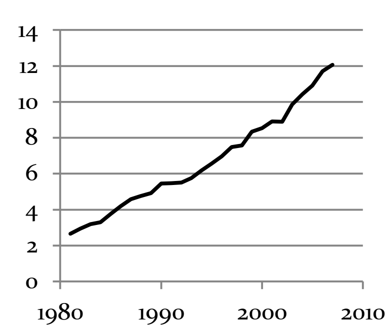
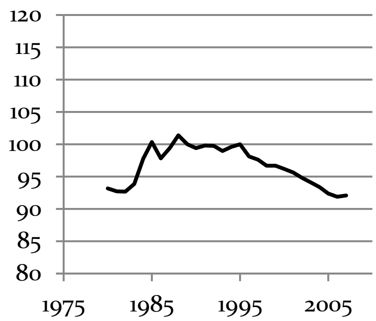


Spain

TFP Index

(1995 = base year)



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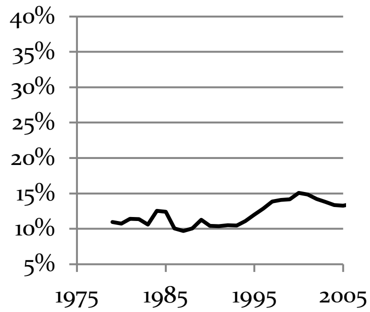

R&D Expenditure

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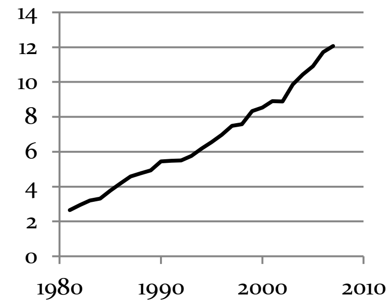
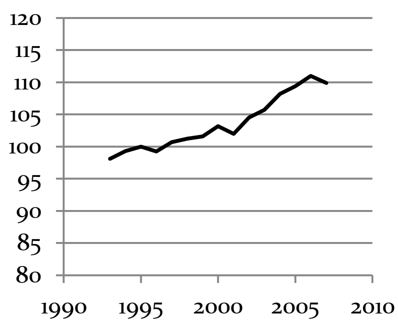


Sweden

TFP Index

(1995 = base year)



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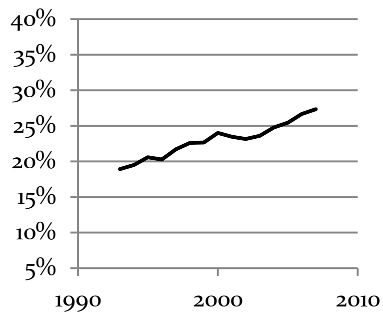
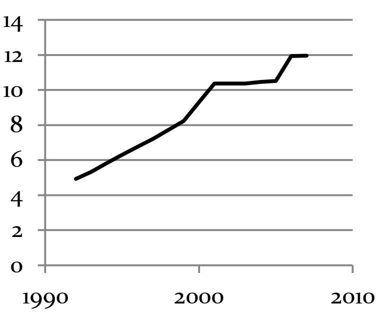


R&D Expenditure

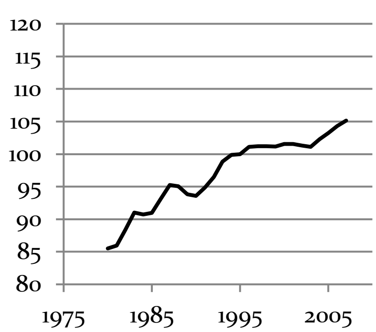
(Billion USD, current PPP)



United Kingdom

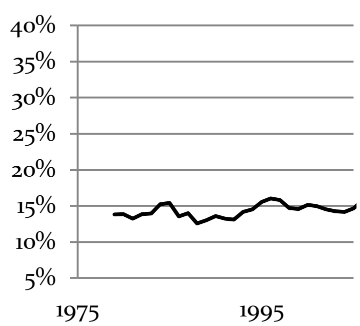
TFP Index

(1995 = base year)



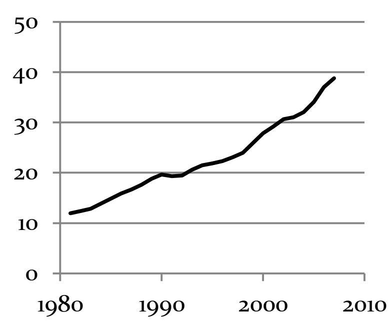
Export Intensity

(Total Export/Total Output)

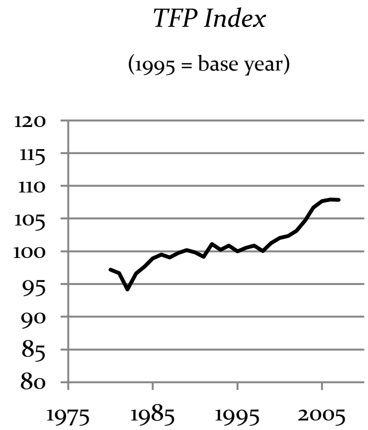


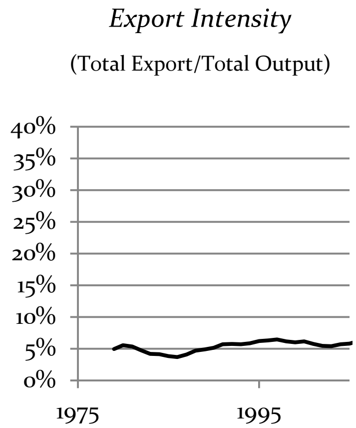
R&D Expenditure

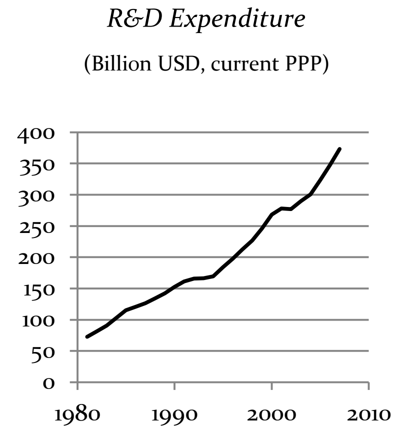
(Billion USD, current PPP)



United States







3. *Miscellaneous tables*

TABLE A *FIXED EFFECT REGRESSION OF TOTAL FACTOR PRODUCTIVITY (USING OPENNESS AS PROXY FOR TRADE INNOVATION), 1981 - 2007*

	Full Panel	Large Market	Small Market	Trade-oriented	Production-oriented
RD	0.0461*** (0.004)	0.0486*** (0.007)	0.0845*** (0.008)	0.042*** (0.005)	0.1245*** (0.009)
TI	0.1434*** (0.029)	0.092* (0.047)	0.1252*** (0.035)	0.2169*** (0.042)	-0.0606⁺ (0.037)
Intercept	3.4978*** (0.095)	3.6554*** (0.143)	3.1975*** (0.104)	3.1852*** (0.1578)	3.3717*** (0.096)
Number of observations	351	189	162	108	243
Period	1981-2007	1981-2007	1981-2007	1981-2007	1981-2007
R^2	0.5361	0.3900	0.7641	0.7318	0.6003

Standard errors are reported in parenthesis. Statistical significance levels at 10%, 5% and 1% are indicated by *, ** and ***, ⁺ t-value is 1.62

TABLE B *IV REGRESSION (USING THE LAGGED INDEPENDENT VARIABLES AS INSTRUMENTS), 1981 - 2007*

	Full Panel	Large Market	Small Market	Trade-oriented	Production-oriented
RD	0.0237***	0.0341***	0.0461***	0.0449***	0.0221***
	(0.002)	(0.005)	(0.006)	(0.006)	(0.004)
TI	0.1435***	0.1347***	0.2354***	0.3555***	0.1521***
	(0.014)	(0.022)	(0.028)	(0.043)	(0.020)
Number of observations	338	182	156	104	234
Period	1981-2007	1981-2007	1981-2007	1981-2007	1981-2007

Standard errors are reported in parenthesis. Statistical significance levels at 10%, 5% and 1% are indicated by *, ** and ***

TABLE C *FIXED EFFECT REGRESSION OF TOTAL FACTOR PRODUCTIVITY (ALL CONTROL VARIABLES), 1981 - 2007*

	Full Sample	Large Market	Small Market	Trad-oriented	Production-oriented
RD	0.0511***	0.0341**	0.0802***	0.1143***	-0.0089
	(4.18)	(2.05)	(4.58)	(5.91)	(-0.53)
TI	0.1124***	-0.0146	0.0287	0.0788	0.0937
	(2.78)	(-0.28)	(0.46)	(1.19)	(2.15)
HC	-0.0149	0.0165	-0.0459*	-0.1561***	0.0801
	(-0.72)	(0.65)	(-1.73)	(-4.21)	(4.19)
TS	-0.0219*	-0.0542	0.0098	0.0360***	-0.1355
	(-1.90)	(0.84)	(0.84)	(3.17)	(-7.53)
OPEN	-0.0397	-0.0724	0.1171**	0.0311	-0.0393
	(-1.06)	(-1.53)	(2.08)	(0.52)	(-0.84)
Intercept	4.2236***	4.4177***	3.459506***	3.9169***	4.4458
	(31.67)	(29.05)	(14.61)	(15.48)	(32.84)
Number of observations	220	100	120	80	140
Period	1981-2007	1981-2007	1981-2007	1981-2007	1981-2007
R^2	0.5386	0.1722	0.7488	0.7654	0.6101

t-values are reported in parenthesis. Statistical significance levels at 10%, 5% and 1% are indicated by *, ** and ***

TABLE D *DESCRIPTIVE STATISTICS OF THE VARIABLES*

Full Sample	N	Min	Max	Mean	Std Dev
TFP	351	68.24306	154.8516	98.41874	9.473463
R&D	351	159.3254	3860315	239238.4	574557.2
Export Intensity	351	0.66751	2.43241	1.212848	0.3079845
Education	297	18.14337	93.78608	47.24258	18.15555
Import share	260	0.1157672	0.6782848	0.4588854	0.1209973
Openness	351	17.17	184.31	66.99946	30.28587

TABLE E *DATA SOURCES*

Variable	Source	Original Currency	Original Frequency
Total Factor Productivity (TFP): *Austria, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, United Kingdom, United States*	EU KLEMS 2009 Database	Not Applicable	Yearly
Total Factor Productivity (TFP): *Canada*	EU KLEMS 2007 Database	Not Applicable	Yearly
Total Output (TO): *Austria* *Finland* *France* *Germany* *Ireland* *Italy* *Netherlands* *Spain*	EU KLEMS 2009 Database	Euro	Yearly
Sweden	EU KLEMS 2009 Database	SEK	Yearly
Denmark	EU KLEMS 2009 Database	DKK	Yearly
United Kingdom	EU KLEMS 2009 Database	GBP	Yearly
United States	EU KLEMS 2009 Database	USD	Yearly
Canada	EU KLEMS 2007 Database	CAD	Yearly
Gross R&D Expenditure (RD)	*OECD Main Statistics and Technology Indicators* (database)	USD	Yearly
Imports of Goods ($IMall$)	*OECD International Trade By Commodity Statistics* (database)	USD	Yearly
Imports of Goods Classified by Sections of SITC 5 and 7 ($IMhigh$)	OECD *Monthly Statistics of International Trade* (database)	USD	Monthly
Imports of Goods Classified by Sections of SITC 8.7 ($IMhigh$)	OECD *Monthly Statistics of International Trade* (database)	USD	Yearly
Exports of Goods and Services (EX)	*OECD International Trade By Commodity Statistics* (database)	USD	Yearly
Gross Enrollment ratio in Tertiary Education (HC)	*UNESCO Institute for Statistics* (Education Statistics Database)	Not Applicable	Yearly
Openness ($OPEN$)	*Penn World Table* (PWT 7)	Not Applicable	Yearly