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Can Countries Create Comparative Advantages?

R&D-expenditures, high-tech exports and country size in
19 OECD-countries, 1981–1999

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ABSTRACT

This paper analyses how increased R&D expenditures and market size influence the distribution of comparative advantage. Previous studies report ambiguous results and also refer to periods when markets were much more segmented and production factors less mobile. The empirical analysis comprises 19 OECD-countries and spans the period 1981 to 1999. It is shown how an increase in R&D-expenditures by one percentage point implies a three-percentage point increase in high-technology exports, whereas market size fails to attain significance. Also institutional factors influence the dynamics of comparative advantage.

Keywords: Dynamic comparative advantage, R&D, market size, institutions

JEL classification: F1, O3

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Introduction

Closer economic integration and increased factor mobility is likely to influence the location of factors of production and thereby the dynamics of comparative advantage. In particular, outlays on R&D and other knowledge augmenting measures, either by private or governmental actors, may be exploited in production sites located in other countries. Thus, increased R&D-expenditures are not necessarily mirrored in a country's production or trade pattern.

In this paper we empirically examine whether countries' increased outlays on R&D is reflected in a higher share of exports of high-technology products, or whether economies of scale and "home" market effects have become more important determinants of countries' specialization and comparative advantage. Both factors have been proposed in the theoretical literature to impact comparative advantage. In addition, we also include institutional factors into the analysis.

According to traditional trade theory the accumulation of knowledge should shift comparative advantage over time and across countries. Even though this view can be traced to the late 19th century, its more modern versions originate in the Rybczynski (1955) mechanism, Arrow's (1962) learning by doing model and Vernon's (1966) product cycle. Also more recent findings seem to confirm the conclusion of earlier models (Redding 1999).

In another strand of the literature, the size of the market has been proposed as a decisive determinant of production. The "home market" effect implies that production (because of lower costs) and labor (because of higher real wages) are attracted to larger markets, i.e., larger countries (Krugman 1980, Fujita et al 1999).¹ Since production of knowledge, or technology, is characterized by economies of scale (Romer 1990; Grossman and Helpman, 1991b) it suggests that R&D-intensive production should be located to larger markets. Still, several small countries – e.g. The Netherlands, Sweden and Switzerland – have a strong position in R&D-intensive industries such as pharmaceuticals, aerospace, and office and computing products. One explanation may be that the nature of knowledge intensive production is quite specialized and that sufficient scale can be attained also in smaller countries (McCann and Mudambi 2004, Cantwell and Mudambi, 2000). Particularly if sales of R&D-intensive products take

¹ This effect has also been confirmed in empirical analyses, see for instance Davies and Weinstein (1999).

place within globally distributed multinational firms. Alternatively, the importance of size has been exaggerated in standard models of location; access to globally competitive knowledge, factors related to the organization of production such as interdependencies between manufacturing and R&D producing units in the firms, links to universities and how well the diffusion of knowledge works within an economy, may be more important than size in attaining comparative advantage.

Empirical evidence is inconclusive. For instance, Fagerberg (1995) has shown that R&D-outlays have a positive effect on production and exports of more technologically advanced goods, whereas the impact of size is more ambiguous. However, previous analyses refer to periods when markets were substantially less integrated and therefore provide little guidance to the current situation among industrialized countries. Moreover, some concern could also be raised as regards the methodological approach applied in earlier studies.

A frequently neglected factor in the analysis of comparative advantage is the differences in countries' institutional set-up. R&D-outlays may have no impact on production and exports if a country lacks the proper institutional set-up to exploit the opportunities originating in such knowledge producing activities. We will implement the share of governmental expenditure in relation to GDP as a proxy for state control of the economy, lack of competition and barriers to entry.² A high governmental expenditure share also reflects potentially high taxes, which can be expected to have a general negative impact on production and may also shift the exploitation (and production) of knowledge – R&D – to manufacturing units in other countries. Hence, these country specific forces must be taken into account as we examine the effect of R&D-expenditures on comparative advantage.

The empirical analysis is based on a data set covering 19 OECD-countries during the period 1981–1999. In the analysis of how R&D-expenditures and market size influence exports of high-technology goods, we implement panel estimations with fixed effects to account for country specific factors – such as different institutional set-ups not captured by government expenditures – that would otherwise bias the result. We control for a number of other variables, such as the endowments of capital and labor, the level of education, outward foreign direct investments, etc. Our prime objective is to shed light

² See Nicoletti *et al*, 1999.

on the empirical explanations of comparative advantage, while more normative aspects of this exercise will be left aside.³

The rest of the paper is organized as follows. In the next section, we briefly recapitulate the theoretical foundations regarding the sources of comparative advantage, as well as previous empirical findings. Thereafter (section 2) the data and the empirical method are presented, together with the hypotheses to be tested. In section 3, the results of the empirical analyses are reported, while section 4 concludes.

1. Theoretical framework

The theoretical literature on dynamic comparative advantage gives a key role to investments in knowledge enhancing activities (particularly R&D) in altering a country's comparative advantage over time. Such dynamic evolution in comparative advantage could either be related to the traditional explanation of specialization in production and trade, i.e. Ricardian (productivity) effects or Heckscher–Ohlin determinants (relative endowments of factors of production). On the other hand, the predictions of the new economic geography models assert that high-tech production is exposed to increasing returns to scale and is therefore likely to agglomerate in larger countries, in the presence of positive trade costs.

To illustrate the conceivable impact of an increase in knowledge capital, defined as R&D-expenditures, consider a simple Heckscher–Ohlin setting of the world. R&D can be viewed as input into production of high-technology goods, either directly or in terms of skilled labor.⁴ Basic trade theory (the Rybczynski theorem) predicts that increased endowment of a factor of production will result in increased supply of goods intensively employing that particular factor. Moreover, a “magnification” effect can be expected, implying that the increase in production exceeds the increase in the factor of production. Eventually, this will show up in increased exports (or decreased imports).

³ See for instance Eaton *et al.* (1998) and Trajtenberg (2002) for normative analyses. See also the strategic trade policy literature (Krugman 1987; Grossman and Helpman 1990; Grossman and Helpman, 1991a; Verspagen 1992; Treffer 1995; Verspagen and Wakelin, 1997).

⁴ Grossman (1989), embarking from the Japanese experience in 1966 to 1986, explicitly modeled the dynamic nature of comparative advantage in a two-sector Heckscher–Ohlin setting, where one sector intensively employed natural resources while the other was assumed to intensively use skill labor. Grossman contended that a strong positive correlation could be observed between R&D-expenditures and the sectors where Japan's comparative advantage had strengthened over time.

Assume a standard Heckscher–Ohlin setting, i.e. the distribution of factor endowments (represented by vector V) between countries remains in the diversification cone in order to maintain factor-price equalization, goods (represented by vector X) markets are characterized by perfect competition, there is no trade costs, etc. If a country's factor endowment changes over time, where superscripts 0 and 1 denote the initial and the end period of observation, and $A(w, IN)$ is the vector of least cost production technologies (w), given the institutional set-up (IN), then,

$$(V^1 - V^0)A(w, IN)(X^1 - X^0) \geq 0. \quad (1)$$

Hence, the dynamic Rybczynski theorem predicts that, over time, there should, on average, be a positive correlation between an increase in a particular factor of production and the good(s) intensively employing it (see for instance Dixit and Norman, 1980).

Alternatively, if we resort to a more Ricardian type of world, comparative advantage is shaped by differences in stock of technological knowledge. In a dynamic setting, past technological change determines the current comparative advantage, which then shapes the rate of learning by doing and technological progress in each sector and each economy.⁵ We retain the notation in expression 1, implying that a vector V of factors are used in the production good. In addition, we also introduce an additional sector in the economy producing Y -goods. Hence, V_y is used to produce Y -goods while V_x is used for the manufacturing of X -goods. Each sector implements technology A at time t . The technology used depends on previous expenditures on R&D, or accumulated production knowledge, represented by R in expression 2,

$$A_j(t) = f(R(t), IN)_j, \quad (2)$$

whereas IN denotes the given institutional set-up and j refers to industry. In a two-sector context, a country will have a comparative advantage in X if,

⁵ In Redding (1999) productivity depends on the stock of sector-specific production experience, which is argued to be positively related to increased R&D-expenditures. See also Krugman (1987) and Lucas (1988) for similar models.

$$\frac{A_x^h}{A_y^h} > \frac{A_x^f}{A_y^f}, \quad (3)$$

where h and f denote the home and foreign country, respectively, and where sub indexes x and y refer to the respective industry.

Consider the case where only the X -sector in two countries employs R&D. Over time, R&D-expenditures are accumulated (or the knowledge stock), which augments the production technology in sector X ,

$$\frac{\partial(A_x^h/A_x^f)}{\partial t} = \frac{\partial(R_x^h/R_x^f)}{\partial t}, \quad (4)$$

implying that an increased expenditure on R&D can be expected to be reflected in improved production technology (A) and enhanced productivity. Thus, an increased expenditure on R&D results in a stronger comparative advantage in X -production. Consequently, both in the Heckscher–Ohlin and the Ricardian world, R&D should have a positive impact on high-technology exports.

The economic geography models referred to in the introduction stress the importance of economies of scale and market size. More sizeable markets allow specialization in the production of intermediate goods, closer and more diversified linkages and a possibility of capturing externalities exceeding that of small countries. This may in turn foster a concentrated spatial distribution of production.⁶ The literature separates between pecuniary linkages, which are defined as either backward linkages (suppliers of intermediate goods) or forward linkages (sizeable demand), and non-pecuniary linkages. The latter refer to knowledge spillovers. Such spillovers are assumed to be local and increasing in market size and geographical proximity is necessary in order to

⁶ *The new economic geography models gained momentum after the contributions provided in the early 1990s (Krugman 1980, 1991a; 1991b). More recently, Krugman's model has been criticized on several grounds, and it has also been modified in different ways, which has led to alternative outcomes (for a survey, see Braunerhjelm et al., 2000).*

profit from these positive externalities.⁷ If R&D is associated with increasing returns to scale in production then, in the presence of trade costs and size differences across countries, production of the increasing return to scale good will predominantly take place in more sizeable countries (Grossman and Helpman, 1991b).

Again, consider a standard two-country (h and f), two-industry world, where n firms produce varieties of high-tech goods (x) and operate on markets characterized by monopolistic competition. Assume that the countries are identical, except with respect to the level of GDP – or expenditure (E) – which is set to unity in country h and E in country f. The larger country will then also host a larger number of n -firms and be a net exporter of high-tech goods.⁸ Since the distribution of firms across the two countries will be determined by,

$$n_h = \frac{\lambda (1 - \rho) E}{(1 - \rho) x} \quad (5)$$

$$n_f = \frac{\lambda (E - \rho)}{(1 - \rho) x}, \quad (6)$$

where λ is the (equal) share of expenditure on high-tech goods and $\rho (< 1)$ is the price ratio determined by trade costs and the elasticity of substitution in consumption. Since expenditure shares are constant for the two goods in the respective country, net trade in high-techs will be driven by the size of the economies,

$$\frac{n_h}{n_f E} \leq 1, \quad (7)$$

and from the equations above, given the numbers of the n firms in the respective country, this is determined by,

⁷ See Fujita and Thisse (1996) and Ottaviano and Puga (1998) for surveys. Keller (2001) provides empirical support for the importance of proximity.

⁸ See Appendix for the basic structure of the model. See also Helpman and Krugman (1985) and Venables (1996).

$$\frac{1 - \rho E}{E - \rho} \quad (8)$$

If the home country (h) is the largest ($E < 1$), then it is also a net exporter of high-tech goods.

The trade and economic geography explanations of production and export specialization disregard differences across countries related to culture, traditions and the institutional setting, which firms are confronted with in their operations. In the first two models above, a variable *IN* referring to the institutional set-up was inserted into the technology matrix (*A*). We view institutions as a shift factor where different institutional designs tend to oppress or promote the utilization and diffusion of a given technology. Previous research has shown how differences in the regulatory framework, property rights, taxes and incentives are closely linked to the innovative process (Bartik 1985; Lieberman 1988; Coughlin et al., 1991; Hill and Munday, 1992). We will therefore include proxies for such variables into the empirical analysis as we examine the determinants of the dynamics of comparative advantage.

2. Data, econometric specification and hypotheses

2.1 The Data

We have pooled data from the OECD, Statistical Compendium with data from the Penn World Tables 6.1. The data span over the period 1981 to 1999 and we have collected data for every second year.⁹ Data on industries refer to ISIC 3 or 4-industry level for the respective country.

To separate between the productions of different technology intensities, we have implemented the standard OECD-classification. Thus, high technology industries comprise: aerospace industry (ISIC 3845), electronic industry (383), office and computing industry (3825), pharmaceutical industry (3522) and instruments (385).¹⁰

⁹ Or closest year available.

¹⁰ The medium technology industries consist of: Industrial chemicals (ISIC 351), other chemicals (352), rubber products (355), plastic products (356), non-ferrous metals (372), machinery, except electrical (382), transport equipment (384) and other manufactured products (390). Remaining manufacturing industries fall into the low-technology category.

2.2 *Econometric specification*

The endogenous variable in our model is defined as a country's exports of high technology products divided by total exports (XHT). We prefer exports to production variables since exports indicate that the products have attained a degree of sophistication or uniqueness that creates a demand for them on international markets. In addition, all countries have increased their exports of high-technology goods in the period we are studying, and the objective of the current paper is to explain this increase. In the period we are examining, the share of exports of high technology products range from 1.2 percent for Australia in 1985 to 38.9 percent for Ireland in 1999. The difference between the highest and the lowest share has been fairly stable throughout the period, around 20 percentage points. Looking at the countries with large shares of high technology exports in the last two decades, two conspicuous characteristics emerge. First, in terms of ranking, there have been few changes among the countries (Table 1). Japan, Switzerland, Ireland and the U.S. hold the four highest positions for the entire period. The second observation apparent from Table 1 is that XHT increases over the whole period for almost all countries. The average increase in the share of high-tech exports between 1981 and 1999 for the OECD-countries is slightly above 8 percentage points. For Ireland, the country experiencing the most substantial increase in its exports of high technology products, the corresponding figure exceeds 23 percentage points between 1981 and 1999.

TABLE 1 HERE

Throughout the analysis, data will be pooled over countries and years, thus giving us a balanced panel of data. Panel regressions with fixed effects will be used to estimate the impact on the dependent variable.¹¹ The error term is expected to exhibit standard properties; that is $\varepsilon_{j,t}$ is assumed to be independently and identically distributed with a zero mean and variance σ^2 for all j and t . Hence, we estimate the following equation,

$$XHT_{j,t} = \beta_1 R \& D_{j,t} + \beta_2 SIZE_{j,t} + \gamma' X_{j,t} + \delta' Z_{j,t} + \varepsilon_{j,t}, \quad (9)$$

¹¹ We conducted a simple F-test to check the validity of using a fixed effect regression, as compared to an OLS, to estimate the regressions. The test clearly rejects the zero hypotheses of all fixed effects jointly being zero.

where j denotes country and t represents time. Our key explanatory variables are the relative level of expenditure on R&D and market size (SIZE). The institutional setting is captured by the fixed effects and the government expenditure variables contained in vector X . We will test whether the coefficients of these variables can be significantly distinguished from zero. Finally, a vector Z is included, representing the remaining control variables. With the exception of a few variables (discussed below), all variables are expressed as shares of GDP.

2.3 Hypotheses on the exogenous variables

In this section, we present the exogenous variables, their definitions and what sign we expect the coefficients to have in the regressions (see Table 2).

TABLE 2 HERE

Previous studies report quite strong support for traditional Ricardian and Heckscher–Ohlin factor endowment explanations of the pattern of trade (Trefler 1995; Davis and Weinstein 1996; Harrigan, 1997; Wolff 1997; Haaland et al. 1998; Gustavsson et al., 1999).¹² Others confer a stronger role to economic geography factors, alternatively to economic geography as well as to the traditional comparative advantage mechanisms (Greenaway and Torstensson 1998; Haaland et al., 1998; Davis and Weinstein 1999; Midelfart-Knarvik et al., 2000). We seek to identify which of these factors that exert the strongest influence on exports of high-technology products over time.

Since our main interest concerns the impact of accumulation of resources on comparative advantage, our knowledge factor of production is defined as R&D relative to GDP.¹³ Figure 1 indicates a positive correlation between R&D-outlays and exports of high-technology goods, even though there is considerable variation around the trend.

¹² See Leamer and Levinsohn (1995) for a survey.

¹³ This is similar to Fagerberg (1995) who studied 19 OECD countries in the period 1960-1983. Torstensson (1998) uses both absolute and relative measures of knowledge endowments in a cross-sectional study covering 23 OECD-countries in 1985. Both measures confer a strong impact of knowledge on exports of high-technology goods. In the present study, the R&D-variable contains both private and public expenditures on R&D, whereof private R&D accounts for approximately 70 percent of the total R&D-expenditures in most OECD-countries.

The relative expenditure on R&D varies from 0.3 percent in Portugal to 3.8 percent in Sweden (Table 3). In accordance with the previous results, we expect an increased share of R&D-expenditure to be positively associated with exports of high-technology goods.¹⁴

FIGURE 1 HERE

TABLE 3 HERE

Ireland stands out as having a very high share of high technology export paired with a relatively low share of R&D. Moreover, the influence of R&D on high technology export seems to be much stronger in Ireland than in the rest of the countries. In order to account for this, we will include an interaction variable between R&D and a country dummy for Ireland in the regressions.

The size variable implemented is defined as each country's GDP in relation to the total GDP of OECD. If size, i.e. scale and linkage factors, is important in producing high-technology goods, this should be confirmed in a positive relation between this variable and XHT. According to theory, such a positive relationship can be expected to prevail.

Comparable data over countries institutional settings is not available over the time period we are considering in the analysis. However, since the institutional setting to a large extent is driven by tradition and "inherited" legal frameworks, it is likely to change slowly within a country. The institutional setting is also likely to be quite different across countries. This in turn implies that the institutional setting to a large extent will be captured by the fixed effects in the regressions.

In addition to the fixed effects, we will also include public expenditure in relation to GDP (GEXP), i.e. the implicit tax structure, as a proxy for how conducive the institutional framework is for turning knowledge into commercialized products. Large public expenditures are claimed to be associated with less entrepreneurial and innovative activity, distorted incentive structures, etc.(Kirzner 1997; Fölster and

¹⁴ See for instance Walker (1979), Dosi and Soete (1985), Soete (1987), Grossman (1989), Dosi et al., (1990), Magnier and Toujais-Bernate (1994), Fagerberg (1995), Braunerhjelm (1996) and Torstensson (1998).

Trofimov 1998; Fölster and Henrekson, 2001). Moreover, a large public sector can also affect production and exports of high-technology goods through crowding out effects (Kneller et al, 2000). If the effect on the workforce mainly involves skilled labor, it should cause XHT to decrease, thereby giving us a negative sign for this coefficient. For instance, in the case of Sweden, highly educated people seem to end up in the public sector. In 1991, almost 60 percent of all people with a university education worked in the public sector (Bergman et al., 1999) while, in the same year, only one third of the total number of employees were occupied in the public sector.

On the other hand, the public sector expenditure share is also related to education, which is likely to have a positive effect on production and exports of high-technology goods. We therefore control for public spending on education as a percentage of GDP (EXPEDU), lagged four years.

In addition to these key variables, we have controlled for a number of other variables, contained in vector Z in equation 9. First, we control for other factors of production than R&D-expenditures, that is, endowments of capital per unit of labor. Due to lack of data, real GDP per capita (RGDPCH) has been used as a proxy for capital per worker.¹⁵ Since high-technology industries frequently display a lower capital-intensity than, for instance, basic- and medium-technology industries, a higher capital per labor ratio is expected to be associated with a smaller share of high-technology exports. In line with previous empirical results (Braunerhjelm 1996), as well as theoretical results (Grossman 1989), a negative coefficient could therefore be expected.

Previous research has shown that foreign direct investment (FDI) is more likely to occur in R&D-intensive industries than in other kinds of industries.¹⁶ In addition, multinational companies (MNCs) can use their R&D as a “blueprint” in many producing units, irrespective of their location. Hence, expanded production of high-technology goods in foreign affiliates is likely to deter exports from home country units. We hypothesize that a negative association prevails between FDI, measured as flows of outward direct investment in relation to GDP, and XHT.

¹⁵ Data for capital per worker is only available up to 1992 in Penn World Tables. The correlation coefficient between capital per worker and real GDP per capita between 1981 and 1992 is, however, very high; 0.79 for the OECD countries.

¹⁶ Evidence based on Swedish data is provided in Braunerhjelm and Ekholm (1998), as well as references to other studies where the same findings are reported.

Alternatively, technology could be exported directly which would appear in payments for patents, royalties, etc. If the technology balance of payments (TBP) exhibits a large surplus, this could be interpreted as if the home country prerequisites to exploit new technology are inferior as compared to other countries. On the other hand, it is also conceivable that the relation between exports of high-technology goods and direct exports of technology is complementary. Consequently, exports of high technology could be the result of a country's ability to develop new technology, whereof some is utilized in production sites at home and some is exported and utilized abroad. Hence, it could be interpreted as a general high capacity to develop new technology within a country. In this case, the impact on XHT is likely to be positive. We have no prior expectations as regards the sign for this variable.¹⁷ This variable is expressed in logarithms. Due to lack of data, both Denmark and Ireland are excluded from the regressions when this variable is included.

One reason advanced in the literature for a weak relationship between R&D-expenditures and exports of high-tech goods is that countries may have specialized in medium-technology production, e.g., car manufacturing (Jakobsson, 1989). Even though production in these industries is not as R&D-intensive as the high technology industries, the sheer size of the medium-technology sector implies that it may absorb a huge part of a country's R&D-resources. In order to control for this, we include a variable defined as the production of medium technology goods, relative to GDP (PMTG). This variable should be negatively correlated with XHT.

Finally, since there has been a positive trend in XHT during the past two decades, we have also included a linear trend variable (for a summary of the exogenous variables, see Table 2).

3. Results of the estimations

The results are reported in Table 4 and 5. The overall explanatory power is at a satisfactory level in all fifteen estimations, ranging from 0.41 to 0.73.

TABLE 4 AND 5 HERE

¹⁷ *Moreover, the quality of this variable is hard to assess.*

In the first regression, we have only included relative R&D-expenditures. On average, an increase in R&D-intensity by one percentage point tends to increase the share of high technology exports by approximately a factor 7. The inclusion of the linear trend variable reduces the factor to slightly below 3. Both these explanatory variables are positive and highly significant in all regressions. Regressions 3 to 9 also incorporate the interaction variable for R&D in Ireland. This variable is, as expected, positive and highly significant in all regressions. The estimated effect of R&D in the other OECD countries is however hardly affected when this variable is introduced.

It is noteworthy that our key variable – market size - has the expected positive sign, but it is insignificant in all regressions. As we control for government expenditures and the variables contained in vector Z (equations 5-9), note that neither the parameter value nor the significance of R&D and size variables change in any major way.

Turning to our proxy for the institutional setting - the share of public sector expenditure (GEXP) - it is shown to have a negative, and in some regressions weakly significantly, impact on the share of exports of high-technology goods. Even though the exact mechanism behind this result is hard to extract at the level of aggregation we are pursuing in the present analysis, it indicates a negative crowding out effect. Alternatively, tax pressure or regulations distort the incentive to engage in production and exports of high-technology goods. Note also that expenditure on education has an unexpected negative influence on exports of high-technology goods, however only weakly significant. One reason for the lack of significance in GEXP when EXPEDU is included could be due to the construction of the variables. Even though expenditure on education is lagged four years, potential positive serial correlation, due to e.g. demographic characteristics, can lead to multicollinearity between this variable and total government expenditure.¹⁸

As regards the remaining control variables, our capital per labor variable is insignificant throughout the regressions and the coefficient varies in sign. On the other hand, production of medium technology goods (PMTG) has the expected negative sign and is significant in all regressions. The outflow of investments (FDI) turns up with an unexpected positive sign, but is insignificant in all regressions. The technological balance of payments (TBP), reported in regressions 10 to 15, is negatively related to high tech export. This result is highly significant in all regressions. Finally, the TREND

¹⁸ Still, regression diagnostics showed no sign of severe multicollinearity.

variable is significant and has the expected sign, i.e., a drift towards increased exports of high-tech goods can be discerned over time.

4. Conclusion

The most clear-cut conclusion from the empirical analysis is that the hypothesis of a dynamic component in comparative advantage is supported, and that this effect is related to investments in R&D. One percentage point increase in R&D investments magnifies the share of high-technology export by approximately three percentage points. We find no impact of country size on exports of high-technology products. Hence, the home market hypothesis is rejected in our analysis. The advantage of a large home country market – that is, better possibilities to exploit economies of scale and more scope for knowledge spillovers – does not seem to off-set exports of high-technology products from smaller countries, even as we control for the obvious outlier in this respect, i.e. Ireland.

The results indicate that traditional trade theory explanations fare much better than economic geography explanations - sizeable home markets - in determining the allocation of production and exports of high-technology products. Knowledge may be so specialized that it can be highly localized, simultaneously as economies of scale are exploited through exports and FDI by firms located in small countries. Similarly, product differentiation and vertical specialization could generate a structure where smaller countries specialize in certain niches and stages of high-technology production. The trade liberalization during the last decades serves to reinforce a development along those lines.

Alternatively, and reflected in our proxy for institutional factors, i.e. the implicit tax pressure which was found to be negative and weakly significant, the regulatory framework and the opportunities for incumbent firms and entrepreneurs to utilize and commercialize knowledge, may complement R&D-investments and be more important than the size of the market in promoting exports of high-technology products. However, the exact nature of how these mechanisms work in influencing the dynamics of comparative advantage remain a task for future research to investigate more thoroughly.

5. Appendix

Assume that the world contains two countries, 1 and 2, producing “high-tech” goods X and low-tech goods Y in the presence of positive trade costs. High-tech goods are exposed to increasing returns to scale; Y -goods are produced under constant returns to scale. X -producers will favor location of production to the larger country in order to exploit economies of scale and avoid trade costs. Hence, the large country will be the net-exporter of high-tech goods.

More precisely, the nested sub-utility function for the high-tech industry is,

$$U_x = \left(\sum_{i=1}^n x_i^\varepsilon \right)^{\frac{\lambda}{\varepsilon}} Y^{1-\lambda}, \quad 0 < \varepsilon < 1, \quad \varepsilon = 1 - \frac{1}{\sigma}, \quad (\text{A.1})$$

where x is the consumption of high-tech X -varieties and Y is the consumption of the constant return to scale good. To simplify the tractability, we can set GDP to one in country 1, without loss of generality, simultaneously as we let GDP equal Y units in country 2 which we denote E . Furthermore, assume that trade costs only apply to high-tech goods, and that these are of the ice-berg type. Finally, we assume that both countries produce both goods to ensure factor price equalization. Aggregate demand for the high-tech goods in the two countries can then be modeled in the following way,

$$D_1 = n_1 x_1 = \left(\frac{n_1 p_1^{-\sigma} \lambda}{n_1 p_1^{1-\sigma} + n_2 (p_2 \tau)^{1-\sigma}} \right) + \left(\frac{n_1 (p_1 \tau)^{-\sigma} \tau E}{n_1 (p_1 \tau)^{1-\sigma} + n_2 p_2} \right) \quad (\text{A.2})$$

$$D_2 = n_2 x_2 = \left(\frac{n_2 (p_2 \tau)^{-\sigma} \lambda}{n_1 p_1^{1-\sigma} + n_2 (p_2 \tau)^{1-\sigma}} \right) + \left(\frac{n_2 p_2^{-\sigma} \tau E}{n_1 (p_1 \tau)^{1-\sigma} + n_2 p_2} \right) \quad (\text{A.3})$$

where the n refers to the number of high-tech firms, x is output per firm, τ is trade costs, and λ represents the expenditure share on high-tech goods. Consequently, the first bracket in the respective expression refers to home-country demand and the second bracket to exports. Since production is exposed to increased returns to scale, each firm's average cost in the X -industry is,

$$AC_{xj} = \eta w + \frac{\mu w}{x_j}, \quad (\text{A.4})$$

where ηw equals constant marginal costs, μw is fixed costs, and x_j represents output per firm. Output per firm, provided that free entry is allowed to ensure that the zero profit (π) condition is retained, can then be calculated as,

$$x_j = \mu \varepsilon / (\pi(1 - \varepsilon)), \quad (\text{A.5})$$

which implies symmetrical output, costs and prices across firms in the X -industry in the two countries when technologies are identical. The equilibrium number of firms is then equal to,

$$\tau^{1-\sigma} = \rho < 1 \quad (\text{A.6})$$

$$n_1 = \frac{\lambda (1 - \rho E)}{(1 - \rho)x} \quad (\text{A.7})$$

$$n_2 = \frac{\lambda (E - \rho)}{(1 - \rho)x}. \quad (\text{A.8})$$

Since expenditure shares on the two goods are constant, net trade in high-tech goods will be driven by,

$$\frac{n_1}{n_2 E} \leq 1 \quad (\text{A.9})$$

and, from the equations above giving the numbers of the n firms in the respective country, this is determined by,

$$\frac{1 - \rho E}{E - \rho}. \quad (\text{A.10})$$

Hence, if the country denoted 1 is the largest ($E < 1$), it is also a net exporter of high-tech good.

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Table 1: Exports of High Technology Products as a Share of Total Exports, %
Relative Rank in Parentheses

	1981		1987		1993		1999	
Japan	17.68	(1)	25.20	(2)	27.30	(2)	28.02	(2)
Switzerland	17.68	(1)	17.47	(4)	20.48	(3)	24.84	(3)
Ireland	15.69	(3)	27.69	(1)	28.95	(1)	38.92	(1)
United States	14.59	(4)	18.43	(3)	18.42	(4)	24.55	(4)
U.K.	10.22	(5)	14.18	(5)	17.56	(5)	21.57	(5)
Germany	8.89	(6)	10.32	(7)	12.18	(9)	15.23	(10)
France	7.72	(7)	11.16	(6)	14.10	(8)	18.20	(9)
Sweden	7.68	(8)	10.15	(8)	14.47	(6)	20.71	(6)
Netherlands	6.57	(9)	9.49	(9)	14.32	(7)	19.46	(8)
Denmark	6.05	(10)	8.82	(10)	9.08	(11)	13.03	(11)
Italy	5.87	(11)	7.28	(11)	8.07	(12)	8.08	(15)
Belgium	5.03	(12)	6.20	(13)	7.53	(13)	10.77	(12)
Canada	4.91	(13)	6.03	(14)	6.87	(15)	9.03	(13)
Austria	4.86	(14)	6.82	(12)	7.35	(14)	8.25	(14)
Portugal	4.55	(15)	3.79	(16)	3.79	(18)	6.30	(16)
Spain	2.71	(16)	3.65	(17)	5.92	(16)	6.23	(17)
Finland	2.55	(17)	6.00	(15)	9.45	(10)	20.37	(7)
Australia	1.73	(18)	1.36	(19)	4.44	(17)	4.79	(18)
Norway	1.57	(19)	3.05	(18)	3.12	(19)	3.91	(19)

Source: *OECD (2002)*.

Table 2: Exogenous Variables and Their Expected Impact on the Share of Exports of High-Technology Products (XHT)

Variable	Description	Source	Note	Expected sign
R&D	Expenditures on R&D as a percentage of GDP (GERD)	OECD (2002)		+
SIZE	GDP as a percentage of OECD GDP, PPP adjusted current dollars	OECD (2002)		+
EXPEDU	Public spending on education as percentage of GDP, lagged four years	World Bank (2002)		+
GEXP	Total disbursements of government as a percentage of GDP	OECD (2002)	Total outlays of government for Mexico and Switzerland	-
FDI	Outward flow of foreign direct investment as a percentage of GDP	OECD (2002) and UNCTAD (2003)		-
PMTG	Production of medium technology industries as a percentage of GDP. ISIC 351, 352, 355, 356, 372, 382, 384 and 390	OECD (2002) and UNIDO (2001)	Due to lack of data approximately 9 percent of the observations have been extrapolated via linear regression technique. Maximum length of extrapolation is three years	-
RGDPCH	Real GDP per capita (Constant price: Chain series) 1996 years int. prices	Heston et al. (2002)	Proxy for capital per worker. Correlation between RGDPCH and KAPW in PWT 5.6 for OECD countries 1981-1992 is 0.79	-
TBP	Technology balance of payments, receipts divided by payments, expressed in logarithms	OECD (2002)		?

Table 3: R&D-Expenditures as a Share of GDP, %
Relative Rank in Parentheses

	1981		1987		1993		1999	
Germany	2.47	(1)	2.87	(2)	2.35	(6)	2.44	(6)
U.K.	2.38	(2)	2.20	(7)	2.05	(8)	1.88	(11)
United States	2.34	(3)	2.69	(4)	2.52	(4)	2.66	(4)
Sweden	2.23	(4)	2.88	(1)	3.27	(1)	3.78	(1)
Switzerland	2.18	(5)	2.82	(3)	2.66	(2)	2.64	(5)
Japan	2.11	(6)	2.57	(5)	2.62	(3)	2.94	(3)
France	1.93	(7)	2.24	(6)	2.40	(5)	2.19	(7)
Netherlands	1.79	(8)	2.20	(7)	1.93	(9)	2.02	(9)
Belgium	1.56	(9)	1.64	(11)	1.70	(12)	1.96	(10)
Canada	1.24	(10)	1.42	(12)	1.70	(12)	1.80	(13)
Norway	1.18	(11)	1.67	(10)	1.73	(11)	1.70	(14)
Finland	1.17	(12)	1.73	(9)	2.17	(7)	3.22	(2)
Austria	1.13	(13)	1.29	(14)	1.47	(15)	1.83	(12)
Denmark	1.06	(14)	1.38	(13)	1.74	(10)	2.09	(8)
Australia	0.95	(15)	1.19	(15)	1.55	(14)	1.51	(15)
Italy	0.88	(16)	1.19	(15)	1.13	(17)	1.04	(17)
Ireland	0.68	(17)	0.83	(17)	1.17	(16)	1.21	(16)
Spain	0.41	(18)	0.61	(18)	0.88	(18)	0.88	(18)
Portugal	0.30	(19)	0.38	(19)	0.61	(19)	0.75	(19)

Source: *OECD (2002)*.

Table 4: Results, Panel Regressions
Dependent Variable: XHT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
R&D	7.53*** (11.69)	2.85*** (3.07)	2.45** (2.39)	2.35** (2.25)	2.42** (2.30)	2.81*** (2.68)	2.81*** (2.76)	2.69*** (2.66)	2.79*** (2.81)
R&D * IRE			11.81*** (2.86)	11.64*** (2.84)	10.74** (2.50)	9.46** (2.23)	10.80** (2.50)	11.86*** (2.71)	11.49*** (2.60)
SIZE				0.25 (1.28)	0.23 (1.19)	0.17 (0.86)	0.17 (0.86)	0.14 (0.69)	0.18 (0.83)
RGDPCH					0.13 (0.70)	-0.03 (-0.14)	-0.03 (-0.16)	0.01 (0.05)	0.003 (0.02)
GEXP						-0.10** (-2.10)	-0.11** (-2.33)	-0.08 (-1.53)	-0.07 (-1.44)
PMTG							-0.14* (-1.96)	-0.15** (-2.20)	-0.13* (-1.81)
FDI								0.09 (1.36)	0.08 (1.23)
EXPEDU									-0.16 (-0.73)
TREND		0.33*** (8.97)	0.32*** (9.18)	0.33*** (8.68)	0.28*** (3.42)	0.33*** (3.70)	0.32*** (3.63)	0.28*** (3.21)	0.29*** (3.22)
F-value	136.6***	95.7***	80.1***	61.2***	49.9***	43.4***	39.0***	35.3***	33.1***
R ²	0.41	0.66	0.70	0.71	0.71	0.71	0.72	0.73	0.73
Number of obs.	190	190	190	190	190	190	190	190	190

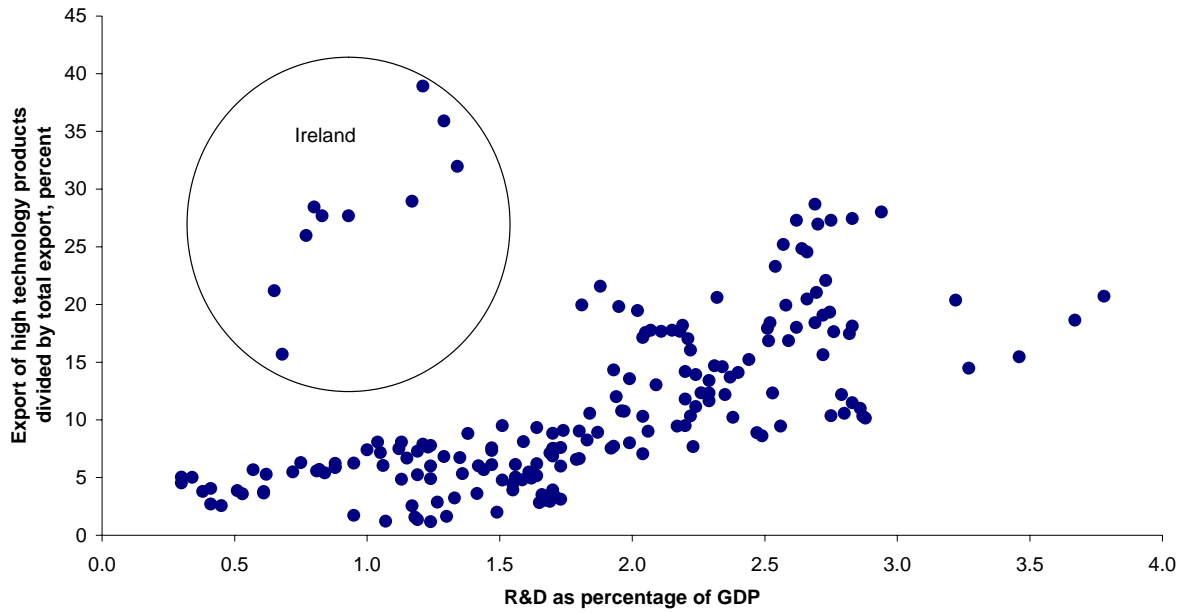
Note: *t*-statistics, based on heteroskedasticity-consistent standard errors (White, 1980), in parentheses. *, ** and *** denote the significance at the 10, 5 and 1 percentage level, respectively.

Table 5: Results, Panel Regressions
Dependent Variable: XHT

	(10)	(11)	(12)	(13)	(14)	(15)
R&D	3.36*** (3.01)	3.34*** (2.92)	3.69*** (3.28)	3.82*** (3.58)	3.68*** (3.45)	4.01*** (3.67)
SIZE	0.29 (1.54)	0.30 (1.58)	0.24 (1.27)	0.27 (1.34)	0.23 (1.15)	0.36 (1.58)
TBP	-0.93** (-2.54)	-0.93** (-2.55)	-0.92*** (-2.61)	-1.13*** (-3.11)	-1.06*** (-3.02)	-1.20*** (-3.23)
RGDPCH		-0.05 (-0.30)	-0.20 (-1.15)	-0.20 (-1.15)	-0.15 (-0.87)	-0.18 (-1.14)
GEXP			-0.09* (-1.92)	-0.11** (-2.25)	-0.08 (-1.59)	-0.07 (-1.41)
PMTG				-0.20*** (-3.13)	-0.21*** (-3.34)	-0.16** (-2.40)
FDI					0.08 (1.35)	0.06 (0.97)
EXPEDU						-0.40* (-1.74)
TREND	0.33*** (8.77)	0.35*** (5.14)	0.40*** (5.39)	0.40*** (5.21)	0.36*** (4.71)	0.37*** (4.99)
F-value	53.8***	46.0***	39.8***	35.7***	32.5***	33.1***
R ²	0.69	0.69	0.70	0.72	0.73	0.73
Number of obs.	170	170	170	170	170	170

Note: *t*-statistics, based on heteroskedasticity-consistent standard errors (White, 1980), in parentheses. *, ** and *** denote the significance at the 10, 5 and 1 percentage level, respectively.

Figure 1: R&D and high technology export in 19 OECD countries 1981-1999



Source: OECD (2002).