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Testing Schumpeterian Growth Theory: The Role of Income Inequality as a Determinant of Research and Development Expenditures (Developed Economies) and Successful Technology Transfers (Developing Economies)

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Abstract

This paper tests a strand of Schumpeterian growth theory that predicts a role for income inequality as a determinant of technology-enhancing activities, in the shape of innovation in the North and of technology transfers in the South. The analysis is conducted at three different levels: by world region, by industrial sector and by country. While the analysis by world region does not produce any clear cut evidence, the analysis by sector yields some evidence that income inequality in the South may have a positive effect on research and development (RnD) expenditures in some industrial sectors located in the North, such as non electricals and pharmaceuticals. Income inequality in both world regions seems also to play a role on the amount of technology that is transferred to the developing world. The sign of the effect might be positive for some sectors and negative for others, but the overall impact is probably negative in the case of Northern income inequality and positive with respect to Southern income inequality.
However, the strongest evidence came from the cross-country analysis. We found that for each of the 15 OECD countries, foreign income inequality in the countries that trade the most with them, had a positive effect on the research and development expenditure carried out in those 15 countries. Such evidence appeared robust to whether we introduced control variables or not, and to several ways of measuring the dependent variable and the independent variables concerned. The cross-country analysis also yielded some evidence of a positive effect of both domestic and foreign (mainly developed world) income inequality on the level of technology transfers to developing countries.

JEL classification: F14, O15, O30
Keywords: Innovation, RnD Expenditures, Technology Transfers, High Tech Exports, Income Inequality

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1. Introduction

Technological progress has long been widely recognized as one of the main engines of economic growth. The literature that brought about such awareness has been around for more than a decade now and goes under the name "Schumpeterian", because it is based on the ideas developed by the famous economist Joseph Schumpeter in his landmark book "Capitalism, Socialism and Democracy" of 1942. Exactly fifty years after Schumpeter published his work, his central concept of creative destruction (his name for technological progress) was revived by Aghion and Howitt (1992), in their article, "A Model of Growth through Creative Destruction". Since then, this concept of creative destruction has gone through many developments and refinements.

The refinement which interests us here is the one whereby creative destruction need not be total, and the degree of creative destruction is modeled as a function of the distribution of income in the economy (Li 2003, Marasco 2002, Zweimuller and Brunner 1998).

In short, the mechanism envisaged in this strand of the Schumpeterian growth literature is the following: the distribution of income determines the structure of the market for quality goods, which may be a pooled market of the best quality or a segmented market of two or more qualities, depending on the magnitude of the average income and on the spread of the distribution around that average. This literature predicts that when the market for quality goods is sufficiently segmented to allow for the presence of two qualities at the same time, an increase in income inequality causes that segmentation to become even more pronounced, so that competition between the two qualities becomes weaker. As the incumbent duopolists become able to charge more for their products, the resulting surge in future expected profits is predicted to act as an incentive that determines an increase in technology advancing activities. By contrast, in those markets where there is a monopoly of the top quality, an increase in income inequality raises the threat of entry of a lower quality competitor that would weaken the monopolist position. In these markets, rising income inequality is predicted to cause a drop in technology advancing activities.

Therefore, the cause-effect relationship goes from income inequality to the degree of competition in product markets, and from the latter to technical change.

The idea that income inequality may have an impact on growth through influencing the mode and the pace of technical progress is relatively novel. The more widely accepted idea has been that income inequality affects growth through physical and human capital accumulation. For instance, Galor and Moav (2004) in a very recent study, reckon that inequality has long been an important determinant of growth. But they argue that over time the channel through which inequality affected growth has changed. In the early stages of industrialization, inequality was thought to be a positive determinant of growth, because physical capital accumulation, in its growth-fostering role, needed a more concentrated, that is unequal, distribution of income to gain sufficient momentum. Later on, as human capital accumulation replaced physical capital accumulation as a prime engine of growth, its characteristic of being embodied in humans implied that in order to display its full potential, human capital accumulation should be widely spread across individuals in society. This time therefore, higher income inequality would be harmful to growth because it would hinder, or at least slow down, such a spread. Galor and Moav attempted to provide a unifying theoretical framework that could reconcile these two effects. However it is interesting to notice that they made no mention of the possibility of existence for a third channel through which inequality could affect growth: technical change.

A direct link between income inequality and technical progress is predicted in theory in a strand of Schumpeterian literature that, given its relevance for the present study, will be reviewed in some greater detail in section 2.1 below. In that literature, the transmission effect from income inequality to technical change is claimed to occur through the effect of income inequality on the degree of competition in product markets and from the latter to technical change. It is therefore important to acknowledge the literature that has studied this second linkage between the degree of competition in products markets and technical progress both from theoretical and empirical standpoints.

From a theoretical standpoint, Aghion et all (2002), predict an inverted U-shaped relationship between product market competition and innovation, while De Nicolo and Zanchettin (2002) predict a positive relationship between competition and innovation when innovations are large enough. Aghion et all also gather empirical evidence in support of their inverted U-shaped hypothesis.

Despite these efforts, there has been no attempt yet, to the best of our knowledge, to gather supportive empirical evidence for the direct link between income inequality and technical progress. In order to fill this gap, we develop an empirical test whose design can best be appreciated after a more detailed description of the theory that underpins it. That is done in section 2.1. Section 2.2 provides some descriptive statistics concerning the data set employed. Section 3 contains the first of three levels of the empirical analysis, the analysis by world region. Section 4 describes the analysis by sector of industry, while section 5 contains the analysis by country. Finally, section 6 concludes.

2.1 The Schumpeterian theory which links income inequality to technical progress

The theoretical literature which predicts a causal relationship between income inequality and technical progress includes the papers by Zweimuller and Brunner (1998), Li (1998 and 2003) and Marasco (2002 and 2004).

All these studies share two common features: first, there are economic agents that seek the monopoly rents which accrue to an innovator because of his/her technological advantage over rivals. Their effort to produce the latest innovation takes place over vertically differentiated quality goods, so that the Schumpeterian process of creative destruction can materialize. This point is the basis of mainstream endogenous growth theory. Second, and here is the novelty of these models, the process of creative destruction is only partial, and the income distribution plays a role because consumer preferences are assumed to be non homothetic over indivisible goods. Consumers' choice is not about how much to buy of the quality good, as in standard Cobb-Douglas like specifications. Instead, it is assumed that consumers buy one unit of the good (indivisibility assumption) and their choice concerns which quality to buy.

All the four papers mentioned above share this common setup. However they differ in the way they model consumers' wealth distribution. In Zweimuller and Brunner 1998, the latter is assumed discrete and consists of two groups, the rich and the poor. As a result, Zweimuller and Brunner predict an inverse relationship between inequality and technical progress.

By contrast, the consumers' wealth distribution is assumed continuous and uniform in Li (1998 and 2003) and in Marasco (2002). That way, the predicted relationship between inequality and innovation is no longer monotonic but it depends on the structure of the market for quality goods. If such a market is a monopoly of the best quality, then more inequality hampers technical progress through weaker incentives for innovators in the form of lower profit expectations. If the market for quality goods is a duopoly, then more inequality provides stronger incentives to innovate.

Marasco (2004) goes one step further and interprets the different market structures in terms of two big regional economic blocs. In the first bloc, the North, the distribution of income is such that the market demands the good of the highest quality only and the market structure there is a monopoly of the incumbent in possession of the latest innovation. As for the Southern bloc, an assumption is made that enterpreneurs based there, can never completely catch up with the state of the art, but, if they try, they might succeed in successfully imitating the quality that sits second from top on the ladder. Because of the different income distribution in the South, both the top quality and the second-from-top quality enjoy positive market share in this region. Hence the structure of the market in the Southern bloc is a duopoly of two qualities.

In such a framework, the predictions of this model are as follows: rising inequality in the Southern bloc raises innovative research efforts in the North, but has an ambiguous impact on the rate of technology transfers to the South.

An increase in Northern inequality has a contrasting effect on the technological advancements of the North and the South. It causes a drop in Northern research efforts, while at the same time promoting an increase in the rate of technology transferred to the South.

2.2 Research design and some descriptive statistics

We pursue our objective by designing an empirical test that resembles the ideal world modeled in the theory as closely as possible. In order to reproduce a setting with two big world regions, one developed and one developing, we gather data from two groups of countries. The first is a group of 15 OECD countries with a combined population of nearly 800 million, that is meant to represent the developed North. The second is a group of 11 developing economies, with a combined population of 2.5 billion at the beginning of the time interval considered (1988), which grows to almost 2.9 billion by the end of that interval (1998). This second group is meant to represent the developing South.

A summary of descriptive demographic and income statistics for both groups of countries is provided in Table 2.2.1 below.

As it can be easily checked with a glance at the table, The 15 OECD countries qualify to be labeled as the developed North, since their income is on average 10 times higher than that of the 11 countries in the second group and less dispersed around its mean, as shown by smaller Gini coefficients than those of the countries in the second group. For specular reasons, those countries in the second group qualify to be termed as the developing South.

As it has been done in the theoretical work, we shall assume that technological progress takes the form of advancement of the technological frontier (innovation) in the Northern region, and of technology transfers in the Southern region. A central issue is how to measure technological progress in the two regions. In order to measure innovation in the North, two of the most common measures used in past literature have been research and development (henceforth RnD) expenditures or patent counts.

We choose to use RnD expenditures, both because suitable time series of RnD expenditure data across the relevant countries are readily available and because patent counts may not be comparable across industries owing to the fact that their value can vary significantly.

In past empirical literature, the focus has mostly been on the alleged impact of RnD on various productivity measures and/or their growth rates. Therefore, RnD has mostly served as an independent, right-hand-side (RHS) variable. There are also some recent studies that use innovation intensity[2], as the dependent variable. One such example is Aghion, Bloom, Blundell, Griffith and Howitt (2002). One difference between that study and ours is that they aim to investigate the effect of product market competition on innovation, while our objective is to probe the effect of income inequality on innovation.

Table 2.2.1 - Summary Population and Income Statistics

15 OECD Economies: **Australia, Canada, Denmark, Finland, France, Germany, Irelan Italy, Japan, Netherlands, Norway Spain, Sweden, U.K., U.S.A.**

Years	Population (units)	GDP per capita (PPP current international dollars)	Average Gini coefficients
1988	721,353,000	18,781	33.96
1989	743,924,000	18,880	33.93
1990	749,209,000	19,740	34.29
1991	753,617,000	20,101	34.21
1992	759,193,000	21,142	34.15
1993	764,689,000	21,626	34.34
1994	769,917,000	22,455	34.51
1995	775,197,000	23,432	34.41
1996	780,390,000	24,267	34.65
1997	785,584,000	24,790	34.92
1998	790,421,000	24,914	35.03

11 Developing Economies: **Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, Rep. Korea, Singapore, Thailand, Turkey**

Years	Population (units)	GDP per capita (PPP current international dollars)	Average Gini coefficients
1988	2,486,156,366	2,086	44.19
1989	2,530,390,220	2,147	44.54
1990	2,574,470,932	2,213	44.77
1991	2,617,505,062	2,329	45.59
1992	2,657,730,100	2,553	45.96
1993	2,697,225,182	2,767	46.00
1994	2,736,011,396	2,991	46.06
1995	2,774,778,916	3,272	46.60
1996	2,813,627,014	3,502	46.83
1997	2,852,669,824	3,655	47.64
1998	2,891,792,956	3,678	47.59

Sources: World Bank (GDP and popul.data), United Nations (Gini coeffs.)

[2] In most studies, innovation intensity is the ratio of some measure of innovative activity, such as RnD expenditures, to gdp.

Other differences concern the way innovation is measured. That study does not use RnD expenditures but patent counts and their data are at firm level, while our data are both at country and industry level.

Figure 2.2.1 below shows the behavior, over the 10-year interval 1988 - 1997, of total RnD expenditures in the 15 OECD countries sampled (the upper line which unites the circles in the graph). It is immediate to notice a non negligible upward trend in the absolute amount of RnD expenditures in the North, which illustrates an increasing effort at innovating in that part of the world.

This figure also shows the behavior of high tech exports in the 11 developing countries sampled (the lower line which unites the triangles in the graph).

Figures 2.2.1, 2.2.2, 2.2.3

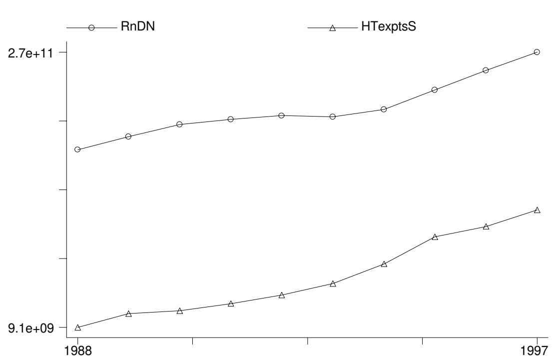

Figure 2.2.1 - RnD Exp. and High Tech Exports

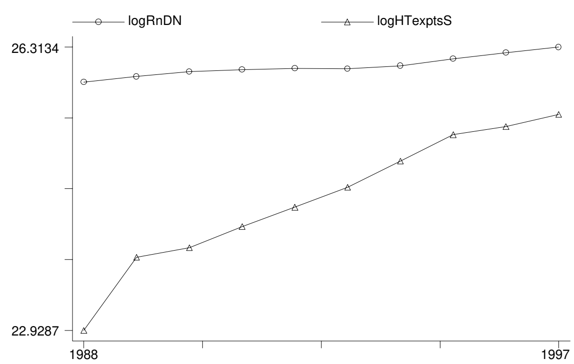

Figure 2.2.2 - Logs of RnD Exp. and High Tech Exports

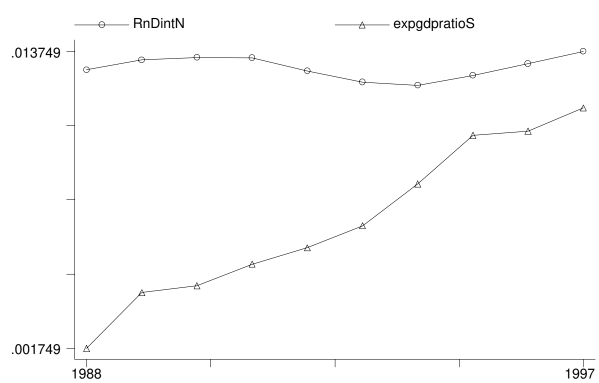

Figure 2.2.3 - RnD and High Tech Export Intensities

High tech exports is our chosen measure of successful technology transfers to the South. Developing countries, which do not perform any significant RnD activity, achieve technological progress when technology that was invented in the North is successfully transferred to them. We make the assumption that if a country that does not carry out significant RnD activities of its own, is able to export goods with high technological content, that technology must have been transferred into the country from the outside at some point. Possible alternative measures of technology transfers might be foreign direct investment (FDI) or high tech imports. But FDI is a much more problematic quantity, which may include purely financial flows, and whose definition varies across countries much more widely than high tech exports. As for high tech imports, it is almost as good a measure as exports, except for the fact that exports may be a more accurate reflection of a country's effective technological capability, since their occurrence can be taken as proof that high tech production has actually occurred. The fact that the high tech exports line in Figure 2.2.1 stays far below that of RnD expenditures is consistent with the widely held belief that only part of the technology invented in the North finds its way to the South. The fact that the line is also characterized by an increasing trend speaks of an equal effort made by the South in trying to keep pace with the North in the field of technological progress. A further feature that emerges from the comparison is that the high tech exports line ever so gradually moves closer to the RnD expenditure line, as shown by its being closer to it at the end of the interval in 1997 than it was at the beginning in 1988. This catch-up story is illustrated even more clearly by Figures 2.2.2 and 2.2.3.

In Figure 2.2.2, where the scale of reporting is logarithmic, the upward trend in RnD expenditures is still present, but to a lesser degree than in figure 1a. Besides, the high tech export line approaches the RnD line at a faster rate. Figure 2.2.3 depicts the 10-year trend in "RnD expenditure to gdp" and "high tech exports to gdp" ratios. The RnD expenditure to gdp ratio does not trend upwards, while the high tech exports to gdp ratio does, thereby approaching the former. Notice however, that the latest three data points in all three graphs are characterized by the two lines running parallel. This feature would seem to confirm the existence of a hard-core advantage held by the North which the South cannot completely eliminate. Such advantage is captured in the theory by the assumption that the South is never less than one step behind the North on the quality ladder.

Given these observed regularities both in the distribution of income and the distribution of technology-advancing activities across time and across world regions, our declared objective is to uncover any relationship that might exist between the pursuit of such technology-advancing activities and specific features of the distribution of income, such as varying degrees of income inequality.

We start from a setup that is as close as possible to the theoretical setup. However, as we become aware of the existence of a trade-off between the level of detail in the analysis and the strength of evidence uncovered, we steadily move away from that theoretical setup, by changing the cross sectional unit of reference from world regions to industrial sectors and finally to countries. the analysis at the regional level is carried out in Section 3, where the two world regions are 15 OECD countries, to represent the developed North, and 11 developing countries, to represent the South. In Section 4 more detail is added as the analysis is performed at the industrial sector's level. the analysis at the cross-country level is described in Section 5.

3. Analysis by World Region

In order to have a close correspondence with Schumpeterian growth theory, we start the analysis at the broadest possible level of aggregation.

Two world regions are considered: a sample of 15 OECD countries, to represent the developed world (at times also referred to as the "North" in the theory), and a sample of 11 developing countries (referred to as the "South" in the theory). The data on the relevant variables are collected at this level of aggregation. Thus there will be region totals or region averages for all variables selected. Before explaining the variables and the criteria used for their selection, we illustrate the econometric model that we shall employ and its rationale.

Since our aim is to test the effect of income inequality in the North and in the South on technology-advancing activities of both regions, in accordance with Schumpeterian growth theory, we posit the following structure:

$$\ln RnD15_t = \alpha_0 + \alpha_1 \ln HTEXPTS11_t + \alpha_2 NG_t + \alpha_3 SG_t + \alpha_4 openness_t + \alpha_5 \ln gdp15 + \varepsilon_1 \qquad (3.1)$$

$$\ln HTEXPTS11_t = \beta_0 + \beta_1 NG_t + \beta_2 SG_t + \beta_3 \ln gdp15_t + \beta_4 \ln pop11_t + \varepsilon_2 \qquad (3.2)$$

The dependent variable in the first equation is RnD expenditures in the sample of 15 OECD countries. On the right hand side, beside the two measures of income inequality NG, the average Gini coefficient for the sample of OECD 15, and SG, the average Gini coefficient for the sample of the developing 11, we control for openness, measured as the average over the sample of OECD 15 of the following ratio, computed for each country: (imports+exports)/gdp. Openness is often claimed to be an important determinant of RnD expenditures. Its impact on RnD expenditures is expected to be positive. We also control for the size of the economy, as measured by total gdp. Again, we expect a positive effect here. In order to address the likelihood of a simultaneity problem, high tech exports from the developing 11 enter equation (3.1) as an independent variable. The reasoning behind this choice stems from the Schumpeterian growth theory and is as follows: RnD expenditures are a measure of innovative activities in the developed world and high tech exports from the developing countries are a measure, albeit a crude one, of how much technology has successfully been transferred to that part of the world from the developed economies. Schumpeterian growth theory predicts that the rate of successful technology transfers to the South determines the pace at which Northern monopolists ultimately exit the market for quality goods. The coefficient attached to high tech exports in the RnD15 equation is expected to be negative, through the following mechanism: the faster is technology transferred to the South, the shorter the tenure of Northern monopolists, the smaller the profit incentives for successful innovators.

In the second equation, high tech exports originating in the sample of 11 developing nations depend on the income inequality of the North and the South, NG and SG, and on two control variables, population of the developing 11, as a measure of the size of the labor force that contributes to the production of those exports, and the gdp of the OECD 15, on the assumption that the larger the destination market of the high tech exports (presumably the OECD 15) the higher the demand for those exports and hence the higher their magnitude.

In both equations above, the variables characterized by very large magnitudes have been logged in order to put them on a comparable scale to the other variables.

We carry out the estimation in two ways. If the endogenous variables are correlated between each other, the OLS method yields consistent estimates of the reduced form coefficients, but since these are linear combinations of the structural coefficients, OLS estimates of the latter are biased. In order to address this problem, we employ instrumental variable (IV) estimation of equations (3.1) and (3.2), also known as two stages least squares (2SLS). The second stage is exactly equation (3.1), while the first stage regression adds openness to the independent variables of equation (3.2)[3]. Table 3.1 shows both 2SLS estimates as just described and OLS estimates of the exogenous variables. The latter are retained in order to serve as a term of comparison for the instrumental variable estimation and for completeness.

Table 3.1 - OLS and 2SLS regression results of logged HTexpts11 and logged RnD15 on selected independent variables, 1988-1997, 10 Observations:

	Dependent Variable			
	LogHTexpts11		LogRnD15	
Independent Variable	OLS	2SLS (first stage)	OLS	2SLS (second stage)
LogHTexpts11	-	-	-	-0.18 (-0.28)
NG	-0.46 (-1.04)	-0.88 (-1.99)	0.05 (0.69)	-0.02 (-0.28)
SG	-0.28 (-1.08)	-0.58 (-2.10)	0.02 (0.65)	0.04 (0.48)
Openness	-	0.10 (1.77)	0.02 (2.60)**	0.02 (2.20)*
loggdp15	-6.26 (-1.00)	-12.59 (-1.98)	0.26 (0.456)	0.386 (0.65)
logpop11	43.83 (2.23)*	65.22 (3.20)**	-	-
Adj. R-Square	0.98	0.97	0.96	0.95
F-test of joint significance	58.16***	66.98***	61.20***	35.38***

*Note: * indicates significant at 10%; ** indicates significant at 5%; *** indicates significant at 1%; t statistics in parentheses.*

We can see that in the case of equation (3.1), the 2SLS estimation yields a negative coefficient for the variable *LogHTexpts11*, as predicted by the theory, but it is not significant. Furthermore, income inequality measures carry a positive coefficient in all cases but one (the exception being 2SLS regression of NG on RnD), but they never approach any significance threshold, as indicated by very low t statistic values, hence it is not possible to make any inference in this case. What does have an effect on RnD expenditures is, in accordance with previous literature, the variable openness. In the case of equation (3.2), the income inequality measures all carry a negative sign. Although they too fail to make the significance thresholds, the higher values of the t statistics indicate that perhaps it might be possible to infer a negative effect of rising income inequality everywhere on the high tech exports of the developing world. But, with only ten observations to work with, we are clearly moving in very shallow waters and the level of aggregation is too broad to make any evidence gathered here credible. In fact, the purpose of this section is to show that an empirical study designed to match Schumpeterian growth theory closely, is seriously constrained by data limitations, hence the necessity to move on and start introducing more detail, in the form of analyses by sector of industry (in Section 4) and by country (in Section 5).

4. Analysis by Sector

In this section, technological advancement is measured, as before, by RnD expenditures in a sample of 15 OECD countries and by high tech exports in a sample of 10 developing

[3] This is because all the exogenous variables of equation (3.1) must be included as instruments in the first stage of the 2SLS estimation, or the estimates will be biased (Baltagi, 1998).

countries, the 11 sampled in section 2 minus Turkey[4]. Furthermore, the data that concern technological advancement, are broken down by sector of industry, following standard categorization of sectors for these types of data.

There are minor differences in the classification of industrial sectors regarding RnD data and export data. In order to facilitate comparisons, we patch up the differences and end up with the following nine industrial sectors, both for the Northern and the Southern samples[5]: aerospace, computing, electronics (communication equipment), electrical, non electrical, chemical, pharmaceutical, armaments (other metal products), items not elsewhere specified.

We denote RnD expenditures in the 15 OECD countries by tn (for "technology North"), and high tech exports in the 10 developing countries by ts (for "technology South").
Since the data are broken down by sector, we shall have tn1, tn2,..., to denote RnD in sector 1 (aerospace), sector 2 (computing) and so on. Likewise, we shall also have ts1, ts2,.., to denote high tech exports in aerospace, computing etc.

The model to be estimated consists of two equations, the first of which concerns the sample of 15 OECD countries, as follows:

$$\ln tn_{st} = a_0 + a_1 NG_t + a_2 SG_t + a_3 \ln gdp15_t + a_4 openness_t + u_1 \qquad (4.1)$$

Where s = 1,2,...,9 indexes sectors, $\ln tn_s$ is the natural log of the OECD 15 total figure of RnD expenditures in sector s, NG and SG are simple averages of Gini coefficients in the OECD 15 and the developing 10 respectively, and the control variables are the logged gdp total of the OECD 15 and openness, which enter equation (4.1) both individually and together. Openness here is calculated as a weighted average of the openness measure specific to each one of the 15 OECD countries included in the sample, and the latter is computed as the ratio (imports+exports)/gdp for each country. The weights are the ratio of each country's gdp to the total gdp for the sample of the OECD 15. Finally, u_1 is an equation-specific error term. In contrast to the preceding section 3, the variable "high tech exports from developing countries" has not been included in the RnD equation (4.1), in order to simplify the analysis without apparent loss of explanatory power, given the lack of evidence gathered in its favor in section 3.

Such equation is estimated according to the random effects model, and the outcome of this regression is reported in Table 4.1 below.

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4 The selection of countries to represent the developing world for this section was made based on a claim in Mani (2000) that the 10 countries selected here account for 90% of all high tech exports originating from the developing world.

5 Sector names are those used for exports according to SITC 3. Whenever sector names for RnD expenditures differ considerably, their names is also shown in parentheses; the last item - not elsewhere specified - contains exports of scientific instruments and RnD expenditures in motor vehicles, other manufacturing and services sectors.

Table 4.1: Random Effects estimates of logged RnD expenditures in the OECD 15 (denoted logtn) on selected independent variables - 90 observations

	Dependent Variable logtn			
Independent Variable	(i)	(ii)	(iii)	(iv)
NG	0.13	0.11	0.11	0.08
SG	0.1***	0.08*	0.09**	0.07
loggdp15	-	0.22	-	0.24
openness15	-	-	0	0
R-square (within)	0.58	0.58	0.58	0.58
Chi2 test of joint significance	107.17***	106.43***	106.28***	105.61***

Note: In random effects estimation, significance thresholds are calculated on the basis of the z (standard normal statistic), and the test of joint significance is chi square. Values shown are coefficient estimates; significance levels as in table 3.1

In the table, there are four regressions, one for each column. Column (i) shows the results when only Northern and Southern Gini coefficients (respectively: NG and SG) are accounted for. Columns (ii) and (iii) show regression results when we control for logged gdp of the OECD 15 and openness respectively. Finally column (iv) shows the regression outcome when the two control variables both appear on the right hand side of equation (4.1).

Income inequality in the developing world, SG, is significant to highly significant and positive in regressions (i) through (iii). This result would confirm the Schumpeterian conjecture that when income inequality is higher in the South, RnD expenditures in the North rise as a consequence of the fact that a more segmented market for quality goods in the South (due to higher inequality) increases profit opportunities for firms that have a market share in that region.

Likewise, the second equation to be estimated concerns the sample of 10 developing countries, as follows:

$$\ln ts_{s\,t} = b_0 + b_1 NG_t + b_2 SG_t + b_3 \ln gdp15_t + b_4 \ln pop10_t + u_2 \qquad (4.2)$$

Where $\ln ts_s$ is the natural log of the total figure for the developing 10 of high tech exports in sector s, the independent variables are as in equation (4.1), except that logged population of the developing 10 is used as a second control variable in place of openness, and u_2 is an equation specific error term. Each variable in both equation (4.1) and (4.2) is measured over the 10-year time period 1988-1997.

Estimation results for this equation, based on the random effects model, are shown in Table 4.2 below.

Table 4.2: Random Effects estimates of logged high tech exports in the developing 10 (denoted logts) on selected independent variables - 90 observations

	Dependent Variable logts			
Independent Variable	(i)	(ii)	(iii)	(iv)
NG	0.35	-0.61*	-0.68**	-0.61*
SG	0.7***	0.06	-0.09	-0.13
loggdp15	-	7.48***	-	-6.79
logpop10	-	-	24.12***	42.97***
R-square (within)	0.77	0.84	0.85	0.86
Chi2 test of joint significance	264.01***	396.12***	447.68***	457.28***

Note: see table 4.1 for details.

The layout of Table 4.2 follows the same pattern as that of Table 4.1. Thus the first column shows regression results with the income inequality measures alone, and columns (ii) to (iv) show regression results when the controls are added, both individually and together. We see that now, unlike the earlier case of Table 4.1, the control variables are highly significant, so that any reversal of results caused by their addition has to be taken seriously. Indeed, a reversal of results is exactly what this estimation exercise produces. Southern inequality goes from being highly significant in clolumn (i) to not making the significance threshold in the other three columns. By contrast, Northern income inequality, which is not significant in the first regression, becomes significant and negative in the latter three regressions. The magnitude of the coefficient remains also almost the same when different control variables are added, which adds credibility to the result. This result says that a rise in income inequality in the rich world has a negative effect on the level of high tech exports from the developing world to that region. This is not the expected outcome, if one is to believe to the strand of Schumpeterian theory briefly outlined in Section 2.1 above. That strand, we recall here, predicts that an increase in Northern inequality causes a drop in Northern research efforts, while at the same time promoting an increase in the rate of technology transferred to the South, which, in this study, are proxied by the South's high tech exports.

At this point we would like to check for the robustness of the above results, and at the same time understand which sectors are responsible for the findings gathered thus far. In order to achieve both objectives, we test each industrial sector separately. The model to be estimated now consists of two sets of nine equations each, one for each industrial sector. The first set of equations concerns the sample of 15 OECD countries, as follows:

$$\begin{aligned} \ln tn_{1t} &= a_{10} + a_{11}NG_t + a_{12}SG_t + a_{13}controls_t + u_1 \\ \ln tn_{2t} &= a_{20} + a_{21}NG_t + a_{22}SG_t + a_{23}controls_t + u_2 \\ &\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ \ln tn_{9t} &= a_{90} + a_{91}NG_t + a_{92}SG_t + a_{93}controls_t + u_9 \end{aligned} \tag{4.3}$$

where s = 1,2,...,9 indexes sectors, $\ln tn_s$ is the natural log of the OECD 15 total figure of RnD expenditures in sector s, NG and SG are simple averages of Gini coefficients in the OECD 15 and the developing 10 respectively, and the control variables are either the logged gdp total of the OECD 15 or their degree of openness. Finally, u_s is an equation specific error term.

Likewise, the second set of equations, concerning the sample of 10 developing countries, is as follows:

$$\begin{aligned}
\ln ts_{1t} &= b_{10} + b_{11}NG_t + b_{12}SG_t + b_{13}controls_t + v_1 \\
\ln ts_{2t} &= b_{20} + b_{21}NG_t + b_{22}SG_t + b_{23}controls_t + v_2 \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
\ln ts_{9t} &= b_{90} + b_{91}NG_t + b_{92}SG_t + b_{93}controls_t + v_9
\end{aligned} \tag{4.4}$$

Where $\ln ts_s$ is the natural log of the total figure for the developing 10 of high tech exports in sector s, the independent variables NG and SG are as in equation (4.1), the control variables are either the logged gdp total of the OECD 15 or the logged population total of the developing 10, and v_{st} is an equation-specific error term. Each variable in both systems (4.3) and (4.4) is measured over the 10-year time period 1988-1997.

Both systems (4.3) and (4.4) may be estimated separately, by OLS, or jointly, by the seemengly unrelated regression (SUR) technique. Since the independent variables are the same in each equation, the coefficient estimates obtained by the two techniques will be the same. The SUR technique additionally allows for the equation specific error terms u_s and v_s to be correlated across sectors, and makes it possible to test for the coefficients attached to each regressor to be jointly zero across sectors. In order to be able to perform such test, the SUR technique is employed for the above sets of equations. Notice that such technique is characterized by a constraint due to the limited number of degrees of freedom. The latter is equal to the number of years considered (10) minus one and minus the number of independent variables included in the RHS of the regression. Therefore, in order to avoid a singular covariance matrix, we have to restrict the analysis to six or seven sectors, depending on how many independent variables are included on the right hand side of the equations. For this reason, in order not to reduce too much the number of sectors studied, only one control variable at a time is added.

Estimation results are shown in a series of six tables; the caption above each table provides detailed info on their specific content.

Table 4.3 - SUR regression of logtn (logged RnD expenditures in the OECD 15) on selected independent variables in computing and electronics sectors - 10 observations per sector

	Dependent Variable Logtn (computing)			Dependent Variable Logtn (electronics)		
Independent variable	(i)	(ii)	(iii)	(i)	(ii)	(iii)
NG	0.24	0.6*	0.06	0.24	0.19	0.06
SG	0.03	0.27**	-0.06	0.08	0.04	-0.01
loggdp15	-	-2.79**	-	-	0.42	-
openness	-	-	0.06	-	-	0.06***
R-square	0.42	0.71	0.52	0.84	0.85	0.94
F-test of joint significance	2.52*	4.81***	2.18	19.06***	11.48***	33.2***

Note: values shown are coefficient estimates; significance levels as in table 3.1

Table 4.4 - SUR regression of logtn (logged RnD expenditures in the OECD 15) on selected independent variables in electrical and non electrical sectors - 10 observations per sector

	Dependent Variable Logtn (electrical)			Dependent Variable Logtn (non electrical)		
Independent variable	(i)	(ii)	(iii)	(i)	(ii)	(iii)
NG	0.19	0.2	0.23	0.14	0	0.11
SG	0.09*	0.09	0.11	0.16***	0.06	0.14**
loggdp15	-	-0.06	-	-	1.17***	-
openness	-	-	-0.01	-	-	0.01
R-square	0.85	0.85	0.86	0.94	0.98	0.95
F-test of joint significance	20.21***	11.56***	12.06***	59.46***	81.42***	35.35***

Note: values shown are coefficient estimates; significance levels as in table 3.1

Table 4.5 - SUR regression of logtn (logged RnD expenditures in the OECD 15) on selected independent variables in chemical and pharmaceutical sectors - 10 observations per sector

	Dependent Variable Logtn (chemical)			Dependent Variable Logtn (pharmaceutical)		
Independent variable	(i)	(ii)	(iii)	(i)	(ii)	(iii)
NG	0.05	-0.02	0.14	0.13	-0.09	0.27
SG	0.06	0.02	0.1**	0.2***	0.05	0.27***
loggdp15	-	0.49	-	-	1.72**	-
openness	-	-	-0.03*	-		-0.04
R-square	0.75	0.78	0.84	0.91	0.96	0.93
F-test of joint significance	10.36***	7.15***	10.4***	34.07***	42.77***	28.18***

Note: values shown are coefficient estimates; significance levels as in table 3.1

Table 4.6 - SUR regression of logts (logged high tech exports in the developing 10) on selected independent variables in computing and electronics sectors - 10 observations per sector

	Dependent Variable Logts (computing)			Dependent Variable Logts (electronics)		
Independent variable	(i)	(ii)	(iii)	(i)	(ii)	(iii)
NG	1.03**	0.48	1.02**	0.6	-0.19	-0.31
SG	0.69***	0.32*	0.79***	0.54***	0.02	-0.21***
loggdp15	-	4.26**	-	-	6.06***	-
logpop10	-	-	-2.2***	-	-	22.22***
R-square	0.97	0.99	0.96	0.93	0.99	0.98
F-test of joint significance	105.51***	137.94***	74,027***	45.02***	341.9***	337.02***

Note: values shown are coefficient estimates; significance levels as in table 3.1

Table 4.7 - SUR regression of logts (logged high tech exports in the developing 10) on selected independent variables in electrical and non electrical sectors - 10 observations per sector

	Dependent Variable Logts (electrical)			Dependent Variable Logts (non electrical)		
Independent variable	(i)	(ii)	(iii)	(i)	(ii)	(iii)
NG	0.64	-0.84	-0.57	0.69	-0.24	-0.39
SG	1.01***	0.03	0.1	0.55***	-0.07	-0.35***
loggdp15	-	11.42***	-	-	7.2***	-
logpop10	-	-	27.57***	-	-	26.57***
R-square	0.9	0.98	0.98	0.91	1	0.98
F-test of joint significance	32.41***	122.48***	98.36***	36.47***	545.15***	203.88***

Note: values shown are coefficient estimates; significance levels as in table 3.1

Table 4.8 - SUR regression of logts (logged high tech exports in the developing 10) on selected independent variables in chemical and pharmaceutical sectors - 10 observations per sector

	Dependent Variable Logts (chemical)			Dependent Variable Logts (pharmaceutical)		
Independent variable	(i)	(ii)	(iii)	(i)	(ii)	(iii)
NG	0.19	-0.86	0.59	0.07	-1.35*	-0.15
SG	0.75**	0.05	1.38***	0.95**	0	1.05***
loggdp15	-	8.12***	-	-	10.97***	-
logpop10	-	-	-16.81***	-	-	-1.03*
R-square	0.85	0.94	0.67	0.85	0.95	0.84
F-test of joint significance	20.46***	31.24***	53.57***	19.26***	40.29***	34,635***

Note: values shown are coefficient estimates; significance levels as in table 3.1

In all tables, R-square and F statistics are provided for all regressions. When reading the results shown in the tables, we seek confirmation for the finding, from Table 4.1, that rising income inequality in the South has a positive effect on RnD expenditures in the North. A glance at the relevant tables (4.3, 4.4 and 4.5) reveals that the sectors which fed that result particularly strongly were computing and chemicals. There is some evidence that the non electrical and pharmaceutical sectors may also have contributed.

As for the analysis of the regressions concerning the sample of 10 developing countries, the situation is probably best understood if the relationship between the two measures of income inequality in the two world regions, denoted NG and SG, and the dependent variable, logged high tech exports from the developing 10 (denoted logts), are described separately. Starting with the relationship between NG and logts, recall from Table 4.2 that NG has a positive but not significant effect if regressed along with SG only on logts (column (i), while the effect becomes negative and significant when control variables are added (columns (ii), (iii), and (iv)). This reversal of results is broadly confirmed by Tables 4.6, 4.7 and 4.8, as far as the signs attached to the coefficients are concerned, but it is not confirmed when it comes to the significance levels. Indeed, only in the computing and pharmaceutical sectors have the significance thresholds been passed. The pharmaceutical sector seems to be responsible for the negative and significant sign obtained in Table 4.2, column (ii), while it is not clear what determines the negative coefficient of column (iii) in the same table. We can only presume that the positive and significant effect obtained in computing is more than offset by the negative (but not significant) effect in the remaining sectors.

In the case of the relationship between SG and logts, Tables 4.6, 4.7 and 4.8 show that all sectors contribute to the positive and significant coefficient of Table 4.2, column (i), while compensating effects between the various sectors are the most likely cause of non significant coefficients of Table 4.2, column (ii) and especially column (iii). If compensating effects are indeed at work, once total gdp or population are controlled for, one should not conclude that Southern income inequality has no significant effects on high tech exports from the South, but rather that income inequality in the South may have sector specific effects of opposite sign that offset each other.

As for the joint test that the coefficients attached to Northern Gini and Southern Gini be zero across sectors, as expected, that hypothesis is strongly rejected in all cases.

To sum up, the sectoral analysis carried out here does produce some evidence that income inequality may have some tangible effect on technology advancing activities. That evidence points to a positive relationship between the level of income inequality in the developing world and the intensity of research activities in the developed world, just as predicted by Schumpeterian theory. The evidence also suggests a link between income inequality everywhere and the level of high tech exports originating from the developing world. That link might be of different sign, depending on the sector of industry, but the overall impact on logts is probably negative in the case of Northern income inequality and positive with respect to Southern income inequality. Such results, if confirmed, would not confirm the predictions of the strand of Schumpeterian growth theory being discussed in this study. Therefore, it should be easy to see what may well be the strongest finding of this section: the need for further analysis, which we duly undertake in the next Section 5.

5. Analysis by Country

5.1 The 15 OECD developed economies.

Up to this point, one recurrent problem has been the fact that, both in the analysis by world region and in the analysis by sector, income inequality measures and the other control variables varied over time but did not vary with the dependent variables across sectors. This lack of variability in the cross sectional dimension, may have been one reason why evidence has been hard to find. In order to overcome such a problem, in section 5 the analysis is performed by country.

In Section 5.1 our focus is on the sample of 15 OECD economies. Income inequality is measured by a domestic Gini coefficient (DG) for each country sampled, and a foreign Gini (FG), also specific to each country sampled. This Foreign Gini is a trade-weighted average of the

Gini coefficients of the biggest trade partners of the country concerned. For each of them, we compute the foreign Gini in four different ways. FG1 is computed across the five biggest trade partners of each country in all commodities. FG2 is computed across the five biggest trade partners in the relevant high tech commodities. FG3 is computed across the six biggest trade partners in the relevant high tech commodities among the pool of 11 developing countries which we call the South. Finally FG4 is computed across the six biggest trade partners in the relevant high tech commodities among the pool of 15 OECD countries which we call the North. The computation of the foreign Gini in four different ways should be seen as an attempt both to perform a sensitivity analysis and to remain as loyal as possible to the theoretical setting of two big world regions. In such a setting, the foreign Gini should be expressed by two variables, one to measure income inequality in the developed world (outside the country concerned), and one to reflect income inequality in the developing world. A simple Gini coefficient calculated across each country's biggest trade partners is not likely to represent those two regions. Our various foreign Gini coefficients are designed to take these issues into account. Since FG1 and FG2 are based on the main trading bloc of each country, these foreign income inequality measures are not based on any particular geographical area. However, since the counterpart in most of the trade done are a few developed economies, FG1 and FG2 tend to be measures which refer to the developed world.[6] FG3 is a measure of income inequality in that part of the developing world that engages in high tech trade with the country concerned. It is meant to resemble the Southern Gini in the earlier analysis. Finally, FG4 is based on high tech developed trade partners of the country concerned, in a bid to resemble the Northern Gini of the earlier analysis.

Equipped with these measures of income inequality, we estimate the following equation:

$$\ln RnD_{it} = \alpha_0 + \alpha_1 DG_{it} + \alpha_2 FG3_{it} + \alpha_3 FGM_{it} + \varepsilon_{it} \qquad (5.1.1)$$

The subscript *i* indexes countries and *t* indexes time. The notation relative to the third regressor is *FGM*, where *M* =1,2,4 to reflect the fact that *FG1*, *FG2* and *FG4* are alternatively used in the equation. We also estimate the same equation with the addition of two control variables, as follows:

$$\ln RnD_{it} = \beta_0 + \beta_1 DG_{it} + \beta_2 FG3_{it} + \beta_3 FGM_{it} + \beta_4 \ln CV1_{it} + \beta_5 Openn_{it} + \varepsilon_{it} \qquad (5.1.2)$$

Where CV1 stands for "control variable 1", which will be the log of gross domestic product (gdp) total or gdp per capita, depending on the regression equation. The second control variable used is openness, calculated as the ratio of total imports + total exports to gdp. Each variable is now measured over the 11-year time period 1988-1998.

As a further robustness check, the selected independent variables have also been regressed on RnD intensity (denoted *RnDint*), calculated as the ratio of RnD total to GDP (in PPP terms), according to the following equations:

$$RnDint_{it} = \gamma_0 + \gamma_1 DG_{it} + \gamma_2 FG3_{it} + \gamma_3 FGM_{it} + \varepsilon_{it} \qquad (5.1.3)$$

$$RnDint_{it} = \delta_0 + \delta_1 DG_{it} + \delta_2 FG3_{it} + \delta_3 FGM_{it} + \delta_4 \ln CV1_{it} + \delta_5 Openn_{it} + \varepsilon_{it} \qquad (5.1.4)$$

[6] Graphs B3 to B17 of Appendix B visually illustrate the fact that FG1, FG2, and FG4 measure roughly the same thing.

Regression results are presented in two tables, one for each dependent variable. The dependent variable is the log of research and development (RnD) expenditures total in Table 5.1.1, and RnD intensity, in Table 5.1.2. Each table is further characterized by 9 regressions. In the first three regressions, only the various Gini coefficients are in turn used as independent variables, as in equations (5.1.1) and (5.1.3), while in regressions (4) to (9) the logs of gdp and gdp per capita, and openness are also alternatively used as control variables, as in equations (5.1.2) and (5.1.4).

Table 5.1.1 - Random effect model estimates of log RnD expenditures on selected independent variables - 165 observations:

	Regr. no.								
Ind var.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
DG	0.02[b]	0.03[c]	0.05[c]	0	0.01	0	0.01	0.01	0.0[b]
FG1	0.12[c]	-	-	0.0[b]	0.03[a]	-	-	-	-
FG2	-	0.11[b]	-	-	-	0.04[c]	0.04[c]	-	-
FG3	0.04[c]	0.04[c]	0.04[c]	0	0	0	0	0	0
FG4	-	-	0.17[c]	-	-	-	-	0.06[c]	0.05[c]
loggdptot	-	-	-	1.12[c]	-	1.1[c]	-	1.09[c]	-
loggdpprc	-	-	-	-	1.27[c]	-	1.210[c]	-	1.198[c]
openn	-	-	-	0.006[a]	0.005[c]	0.005[c]	0.005[c]	0.005[c]	0.004[c]
R-sq. wi	0.51	0.53	0.56	0.71	0.73	0.73	0.74	0.72	0.74
R-sq. be	0.02	0.02	0.02	0.91	0.02	0.91	0.03	0.91	0.04
R-sq. ov	0.03	0.03	0.03	0.91	0.04	0.9	0.05	0.9	0.06
Haus. stat.	0.03	0.01	0	2.82	0	2.84	0	3.04	0
Hauss. p-value	1	1	1	0.73	1	0.72	1	0.69	1

Note: values shown are coefficient estimates; a = significant at 10%; b = significant at 5%; c = significant at 1%; DG = domestic Gini; FG1 = foreign Gini based on the five biggest trade partners of each country in all commodities*; FG2 = foreign Gini based on the five biggest trade partners in the relevant high tech commodities; FG3 = foreign Gini based on the six biggest trade partners in the relevant high tech commodities among the pool of 11 developing countries; FG4 = foreign Gini based on the six biggest trade partners in the relevant high tech commodities among the pool of 15 OECD countries; loggdptot is the log of total gdp in PPP current international dollars*; *loggdpprc is the log of per capita gdp computed as total gdp divided by total population; openness is the ratio (imports+exports)/gdp. R-sq. wi = R-square within, R-sq. be = R-square between, R-sq. ov = R-square overall.*

A glance at Table 5.1.1 reveals that, when considered on their own, all the various Gini coefficients have a positive and significant impact on the log of RnD expenditures. The main problem with these regressions is that the positive sign of the coefficients attached to the independent variables might still be determined by some other variable that is not explicitly considered in those first three regressions. This issue is addressed in Table 5.1.1 by introducing two control variables that the previous literature on RnD considers to be important determinants of RnD expenditures: gross domestic product (gdp) and the degree of openness of the relevant economy. Thus in regressions (4), (6) and (8) the controls are gdp total and openness, while in regressions (5), (7) and (9) we control for gdp per capita and openness. What we see is that, after adding the controls, domestic Gini and FG3 lose their significance, whereas foreign Gini measures calculated on partners from the developed region (FG1, FG2 and FG4) are still very significant and positive.

Table 5.1.2 - Random effect model estimates of RnD intensities on selected independent variables - 165 observations:

	Regr. no.								
Ind var.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
DG	0	0.01	0.02[c]	0	0	0	0	0.01	0.014[a]
FG1	0.068[c]	-	-	0.045[c]	0.05[c]	-	-	-	-
FG2	-	0.073[c]	-	-	-	0.056[c]	0.059[c]	-	-
FG3	-0.01	-0.013[a]	0	-0.017[b]	-0.014[a]	-0.018[b]	-0.015[b]	-0.013[a]	-0.01
FG4	-	-	.089[c]	-	-	-	-	0.059[c]	0.063[c]
lngdptot	-	-	-	0.08	-	0.05	-	0.07	-
lngdpprc	-	-	-	-	-0.01	-	-0.04	-	0
openn	-	-	-	0.006[c]	0.006[c]	0.005[c]	0.005[c]	0.005[c]	0.005[c]
R-sq. wi	0.24	0.33	0.27	0.33	0.34	0.39	0.39	0.33	0.34
R-sq. be	0.07	0	0	0	0.02	0	0.05	0	0.05
R-sq. ov	0.09	0.02	0.01	0.03	0	0	0.01	0	0.01
Haus. stat.	0.08	0.39	0.75	5.47	7.76	5.73	4.18	4.77	4.36
Hauss. p-value	0.99	0.94	0.86	0.36	0.17	0.33	0.52	0.45	0.5

Note: values shown are coefficient estimates; significance levels, Gini measures, control variables and R-square statistics as in table 5a.1.

Table 5.1.2 yields a less clear cut picture, with respect to DG and FG3, which sometimes are not significant. Moreover, when controls are added, FG3 is characterized by a significant but negative coefficient. Despite these complications, table 5a.2 confirms the evidence that FG1, FG2 and FG4 all have a positive effect on the level of RnD expenditure.

Tables 5.1.1 and 5.1.2 also show R-square coefficients and Hausman test statistics for all regressions. We start with a comment on the Hausman test and deal with the R-square coefficients later. The Hausman test is used here to decide between employing the fixed effects or the random effects estimation technique. The fixed effects model assumes that time-invariant country-specific effects are correlated with the independent regressors, and treats them as fixed components of the intercept. On the other hand, the random effects model assumes that there is no correlation between these country specific effects and the regressors. Under the hypothesis of no correlation, both OLS and GLS estimates are consistent. A low value of the Hausman test statistic (and a high p value) indicates that any difference in estimated coefficients under OLS and GLS is not systematic, and the random effects model should be preferred. High values of the Hausman test statistic, along with low p-values ($p < 0.05$) imply rejection of the null hypothesis that differences in OLS and GLS coefficients is not systematic. In that case, the fixed effects model should be employed. By looking at the values in the three tables, the case for using random effects estimates is overwhelming. As for R-square coefficients, we use them to assess the goodness of fit of each regression, so to have some guiding criterion, for declaring a preference of some regressions over others. We see that R-square coefficients are high for regressions (4), (6) and (8) of Table 5.1.1, and, with the exception of the within R-square in some cases, they are low, or very low, elsewhere. It is a well known feature of R-square coefficients that they increase in magnitude as more independent variables are added to a regression, and that this surge in magnitude does not necessarily reflect a better fit. Nevertheless, the striking difference between R-square coefficients in this case should leave the analyst in no doubt that this is indeed an instance where regressions (4), (6) and (8) of table 5a.1 do represent a better fit. When we look at how plausible regression coefficients are and at the goodness of fit of the various regressions, our preference goes to regressions (4), (6) and (8) of table 5a.1. The evidence from these regressions is that foreign income inequality in the main trade area of each country sampled, however measured (by FG1, FG2 or FG4), has a significant and positive impact on the level of RnD expenditures. Such result is certainly the strongest piece of evidence that emerges with respect to the 15 developed countries sampled, and it appears robust to whether we introduce control variables or not, and to several ways of measuring the dependent variable and the independent variables concerned. On the contrary, domestic income inequality (DG), and income inequality in the developing 11 (FG3), do not appear to have any significant influence on RnD expenditures of the developed 15.

How do these results fare when compared with Schumpeterian growth theory? The regressors FG1, FG2 and FG4 which are meant to measure income inequality in the North, matter as predicted by the theory, but they are wrongly signed. This discrepancy could be explained by recalling the detail of the theoretical setup. In the latter, the crucial factor that causes the distribution of income to have a negative or a positive effect on the level of innovative activities in a given region, is whether the market for quality goods in that region is pooled or segmented. Such a market structure, in turn, is supposed to depend on the regional distribution of income. It might be that, in practice, the distribution of income in the countries used for calculating FG1, FG2 and FG4 is such that the market for quality goods in those countries is segmented, not pooled. If this were the case, those countries would actually have to be included in the South, not the North. Nevertheless, the distribution of income in most of the 15 OECD countries that comprise the North probably satisfies the condition for a pooled quality good market. Therefore such an explanation is extremely unlikely to apply to FG4, which was calculated entirely on the basis of countries located in the group of OECD 15.

An alternative explanation is that the relevant theory which is more successful at explaining the real world is not the first strand of Schumpeterian growth literature, but the more recent refinements that replace leapfrogging with neck-and-neck competition. In this more recent literature, stiffer competition in the quality goods market pushes levels of innovation intensity higher, due to an escape competition effect that more than offsets the original Schumpeterian negative effect.

The non significance of the coefficient attached to FG3 is somewhat justified by the fact that the trade in high tech goods occurring between the OECD 15 and the developing countries sampled here is too small a fraction of the total for the distribution of income in the latter countries to have any effect.

More puzzling is the lack of evidence regarding the domestic Gini coefficient. At first sight, it would seem that whatever mechanism is in force that makes changes in the distribution of income in a country's trade partners be felt in the level of innovative activity in that country, should also be at work to make the domestic distribution of income a factor in the activities of innovators in that country. At present, we have no plausible explanation to offer for this apparent discrepancy of results between the domestic and foreign Gini coefficients.

5.2 The 11 developing economies.

In this section, we stick to the assumption that high tech exports are a good proxy for successful technology transfers to a developing country. The role of both domestic and foreign income inequality as a determinant of those high tech exports is investigated for a cross section of 11 developing countries over the time interval 1988 - 1998. To this end, the following equation is estimated:

$$\ln HTEXPTS_{it} = \alpha_0 + \alpha_1 DG_{it} + \alpha_2 FG_{it} + \varepsilon_{it} \qquad (5.2.1)$$

where *DG* is domestic Gini and *FG* stands for foreign Gini, which is calculated, as before, as a weighted average of the Gini coefficients of each country's five biggest trade partners, the weights being the volume of trade.

In this case, unlike section 5.1, we did not feel it was necessary to compute the foreign Gini in several ways. Insofar as the main trade partners of the 11 countries sampled here are most frequently located in the developed world, the foreign Gini measure reflects fairly well income inequality in the North. Results from estimation of equation (5.2.1) are reported in Table 5.2.1 sub column (1) below:

Table 5.2.1 - Fixed effect model estimates of log high tech exports on selected independent variables:

	Regression no		
Indep. variable	(1)	(2)	(3)
DG	0.172***	0.05	0.055*
FG	0.205***	0.02	0.065*
loggdptot	-	2.34***	-
loggdpprc	-	-	2.569 ***
rel.exch.rates	-	0	0
R-sq. wi	0.51	0.77	0.73
R-sq. be	0	0.16	0.25
R-sq. ov	0.04	0.05	0.3
Haus. stat.	10.82	231	56.73
Haus. p-value	0.0045***	0.0000***	0.0000***

Note: values shown are coefficient estimates; significance levels as in table 3.1; DG = domestic Gini; FG = foreign Gini; loggdptot and *loggdpprc as in table 5a.1; real exch. rates = real exchange rates*; *R-sq. wi = R-square within, R-sq. be = R-square between, R-sq. ov = R-square overall.*

In the same table, column (2) presents regression results when the log of total gdp and real exchange rates are controlled for, while in regression sub column (3) the control variables are log of gdp per capita and real exchange rates.

Domestic Gini and foreign Gini are both highly significant and positive when considered on their own, but not so when the log of gdp total is used as a control. Notice however that they pass the 10% significance threshold when gdp per capita is controlled for. One reason to prefer the regression of column (3) to that of column (2) is that, since gdp per capita is less likely to display a time trend than total gdp (the former is stationary when the latter grows at the same rate as the population), and since trended variables are notoriously more prone to produce spurious results, the output of column (3) is likely to be more accurate than that of column (2). As for real exchange rates, the fact that they turn out not to have any impact on high tech exports may be explained by the fact that high tech exports generally do not compete on price.

Table 5.2.1 presents R-square and Hausman test statistics for the same regressions. The values of Hausman tests here are all highly significant and justify estimation by the fixed effect model in this case.

As for R-square statistics, values are very low in the case of regressions sub column (1) and (2), but they rise non negligibly when gdp per capita is controlled for (regression sub column (3)). Such a higher R-square coefficient provides one further reason for us to prefer the regression sub column (3). Therefore, we tentatively conclude, based on this regression, that the analysis carried out in this section yields some evidence that both domestic income inequality and foreign (mainly developed world) income inequality have a positive effect on the level of high tech exports in developing countries. Such results, although not as strong as we would like it to be, is nonetheless completely novel. As far as we know, this is the first time that some link is being established between the technological progress of a developing country, and both its domestic income distribution and the income distribution of its main trade partners. Furthermore, these findings, particularly the one concerning the foreign Gini, are in line with the strand of Schumpeterian growth theory when it predicts an increase in Northern income inequality to have a positive effect on the rate of technology that is successfully transferred to the South.

6. Conclusion

This study has investigated the role played by income inequality as a determinant of technology-advancing activities, both in the developed world (the "North") in the shape of innovation, and in the developing world (the "South") in the shape of successful technology transfers. Technology-advancing activities were measured by RnD expenditures in the North and by high tech exports in the South. The analysis has been conducted at three different levels: by world region, by industrial sector, and by country.

While the analysis by world region did not produce any clear cut evidence, the analysis by sector yielded some evidence that income inequality in the South may have a positive effect on RnD expenditures in some industrial sectors, such as non electricals and pharmaceuticals. The evidence also suggested a link between income inequality in the North and the South and the level of high tech exports originating from the developing world. That link might be of different sign, depending on the sector of industry, but the overall impact on logts is probably negative in the case of Northern income inequality and positive with respect to Southern income inequality.

However, the strongest evidence came from the cross-country analysis. We found that for each of the 15 OECD countries, foreign income inequality in the countries that trade the most with them, had a positive effect on the research and development expenditure carried out in those 15 countries. Such evidence appeared robust to whether we introduced control variables or not, and to several ways of measuring the dependent variable and the independent variables concerned. We also found that both domestic income inequality and foreign (mainly developed world) income inequality had a positive effect on the level of high tech exports in developing countries.

The cross country findings concerning income inequality as a possible determinant of RnD expenditures in developed countries, do not support the strand of Schumpeterian growth theory which was briefly explained in section 2.1, and which this study tried to appraise. That theory predicts a negative effect of Northern income inequality on Northern innovative activities, owing to the negative effect that a stiffer competition in the Northern product market (due to higher inequality) has on the innovative activities of that region. Such findings may however be in line with a more recent strand of Schumpeterian growth literature which predicts a positive effect of increased competition on innovative activities in the North, through an escape competition effect that kicks in if outsiders cannot leapfrog incumbents but have to race neck-and-neck with them, and that more than offsets the standard negative Schumpeterian effect.

As for the cross country findings relative to the determinants of high tech exports in the developing world, although not as strong as those relative to Northern RnD, they still represent a novel element that should be taken into account by future work in this area.

Suggestions for such future work may include refinements in the econometric techniques used, for example by relaxing the assumption that the relationship between variables is linear, and variations to the ways innovation and technology transfers are measured.

Finally, given that the theory posits the effect of income inequality on technology-advancing activities to occur through changes in product markets structure and competition, it might be of great interest to bring this latter element explicitly into the empirical analysis. This might be achieved for example by performing a 2 stages least squares estimation, where in the first stage income inequality is regressed on the degree of product market competition and in the second stage, the latter is regressed on some measure of innovative or technology-transferring activity.

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Appendix A - Data sources and methods

A1. Research and Development Expenditures

Data on Research and Development expenditures come from the OECD ANBERD Database. The data, in PPP dollars, refer to the following 15 OECD countries: Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, Spain, United Kingdom, United States.

The variable RnD15 of section 2 is calculated as total manufacturing RnD expenditures in the 15 OECD countries sampled.

The variables tn1, tn2,..., tn9 of section 3 are RnD expenditures totals for the 15 OECD countries in each of the following industrial (manufacturing) sectors: aircraft, computing, communication equipment, electrical, non electrical, chemical, pharmaceutical, other metal products, items not elsewhere specified.

The variable RnD_i of section 4 is total RnD expenditures in manufacturing for country *i*.

A2. High Tech Exports

High tech exports figures were calculated on the basis of exports data from the U. N. Comtrade database. Figures concern the following 11 developing countries: Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, Rep. Korea, Singapore, Thailand, Turkey. Mani (2000) calculates that 10 of the 11 countries listed here (Turkey is not included) contributed about 90 per cent of the total exports of manufactures from the developing world in the period 1991 - 1997. We added Turkey to the sample because we found that it was the country that contributed the most of the remaining 10 per cent (notice however that Turkey is not included for the sectoral analysis carried out in section 3).

To decide whether exports should qualify as having high technological content, we rely on a table provided by Mani (2000), who reports a classification based on OECD definitions of high technology by Hatzichronoglu (1997), made according to SITC (Standard Trade Classification) Revision 3. That table is shown below:

Table A1 - High Tech Products List by OECD (Based on SITC Rev. 3)

Product Description	**SITC Revision 3 Codes**
Aerospace	Sum (7922....7925) Sum (71441....71491)
Computing and Office Equipment	75113, Sum (75131...75134), Sum (7521...7527), 75997
Electronics and Telecommunications	76381, 76383, Sum (7641...76492), 7722, 77261, 77318, 77625, 77627, 7763, 7764, 7768, 89879
Electrical Equipment	Sum (77862...77865), 7787, 77884
Non Electrical Equipment	71489, 71499, 71871, 71877, 71878, 72847, 7311, 73131, 73135, 73142, 73144, 73151, 73153, 73161, 73163, 73165, 73312, 73314, 73316, 7359, 73733, 73735
Scientific Instruments	Sum (7741...7742), 8713, 8714, 8719, 87211, Sum (87412...8749), 88111,88121, 88411, 88419, 89961, 89963, 89966, 89967
Chemical Products	Sum (52222...52269), 5251, 5259, 5311, 5312, 57433, 5911, 5912, 5913, 5914
Pharmaceutical	5413, 5415, 5416, 5421, 5422
Armaments	8911, 8912, 8913, 8919

Source: Hatzichronoglou (1997) as reported in Mani (2000)

The *HTEXPTS11* variable of section 2 is calculated as the total export figure for the commodities listed in table A1 across the 11 developing countries sampled.
The ts1, ts2, ..., ts9 variables of section 3 are export totals across 10 developing countries (the 11 of section 2 minus Turkey) for the commodities listed in table A1 in each of the following industrial (manufacturing) sectors: aerospace, computing, electronics, electrical, non electrical, chemical, pharmaceutical, armaments, items not elsewhere specified.

The $HTEXPTS_i$ variable of section 4 is total exports for the commodities listed in table A1 for country *i*.

A3. Gini Coefficients

Gini coefficients for both the 15 OECD countries and the 11 developing countries sampled have been calculated on the basis of the United Nations World Income Inequality

Database (U.N.W.I.I.D.), for the period 1988 - 1998. This database is a comprehensive collection of all the existing primary sources of data on income inequality. Two are the problems that any user of this database faces: first, on the time dimension, many data points are missing. Secondly, magnitudes of Gini coefficients vary a great deal, depending on factors such as the income definition upon which the Gini coefficient is calculated (gross income, net income and so on), the reference unit used (person, household and so on) and the source of the data.

In order to achieve consistency over time and across countries, wherever possible the following criteria were adopted:

1) use Gini coefficients based on gross income as the income definition;
2) employ the same data source, mainly the Luxembourg Income Survey, as much as possible;
3) use Gini coefficients based on household as the reference unit.

Wherever data for a particular year or longer time interval are alltogether missing, we interpolate by using the available extremes of the relevant time interval. If data are missing for the preferred data source, income definition or reference unit but coefficients are available under different criteria, we interpolate assuming that the missing coefficients change at the same rate as those available under different criteria. If data based on gross income are not available throughout the period, where possible we use coefficients based on net income and add a constant c (generally $c = 5$), in accordance with the guidelines of the U.N.W.I.I.D.

Finally, when no interpolation is possible, we assume that the coefficient remains constant throughout the missing years (typically such an instance occurs towards the end of the time interval).

The Northern Gini coefficient of sections 2 and 3 is a simple average of the Gini coefficients of the 15 OECD countries sampled. Likewise, the Southern Gini coefficient of section 2 is the simple average of the 11 developing countries sampled. In section 3, the simple average was calculated over 10 countries (Turkey was not included in the calculation).

The FG1, FG2, FG3 and FG4 are trade-weighted average Gini coefficients calculated as follows: FG1 of country i is the trade-weighted average Gini coefficient of the 5 biggest trade partners of country i. In symbols: $FG1_i = \sum_{j=1}^{5} w_{ij} G_j$ where j indexes countries and the weights w_{ij} are the ratio of value of trade of country j with country i in all commodities above total value of trade of country i in all commodities. FG2 is like FG1, except that the weights are calculated for the value of trade in the subset of high tech commodities as defined in table A1. FG3 of country i is the trade-weighted average Gini coefficient of the 6 biggest trade partners of country i among the developing 11 in the subset of high tech commodities. The calculation is as before, but j is now an element of the set of 11 developing countries, and the weights are calculated as the ratio of value of trade of country j with country i in high tech commodities above total value of trade of country i in high tech commodities. Finally, FG4 is like FG3, except that j now indexes the set of 15 OECD countries.

A4. Control Variables

Data sources for the control variables are as follows: gdp and population data, both for the 15 OECD countries and the 11 developing countries included in the study, come from the World Development Indicators Database of the World Bank. The variables "openness" and "real exchange rates" are from the Penn World Tables 6.0.

Appendix B - Other Tables and Graphs

In this Appendix we present those graphs and tables that did not find space in the main text, yet are very useful for understanding the main features of the data.

Tables B1 to B4:

Table B1 - Correlations and basic statistics for variables in Section 3

	logRnD15	logHTexpts11	loggdp15	logpop11	openn15	NG	SG
logRnD15	1						
logHTexpts11	0.94	1					
loggdp15	0.96	0.98	1				
logpop11	0.96	0.98	1	1			
openn15	0.97	0.87	0.9	0.89	1		
NG	0.94	0.88	0.92	0.92	0.9	1	
SG	0.96	0.95	0.97	0.98	0.91	0.9	1
Mean	26.09	24.49	30.42	21.71	33.5	34.34	45.82
St.Dev.	0.13	0.82	0.13	0.05	2.64	0.3	1.08
Min.	25.89	22.93	30.24	21.63	30.42	33.93	44.19
Max.	26.31	25.51	30.6	21.77	39.04	34.92	47.64

Note: See main text for definitions of variables

Table B2 - Correlations and basic statistics for variables in section 4

	logtn	logts	NG	SG	loggdp15	openn15	logpop10
logtn	1						
logts	0.43	1					
NG	0.22	0.39	1				
SG	0.23	0.42	0.9	1			
loggdp15	0.23	0.44	0.92	0.96	1		
openn15	0.22	0.38	0.9	0.93	0.9	1	
logpop10	0.23	0.44	0.92	0.96	1	0.89	1
Mean	23.84	21.14	34.34	45.7	30.42	33.5	21.71
St.Dev.	0.58	1.79	0.29	0.94	0.12	2.52	0.04
Min.	22.97	16.72	33.93	44.29	30.24	30.42	21.63
Max.	25.43	25.04	34.92	47.5	30.6	39.04	21.77

Note: See main text for definitions of variables

Table B3 - Correlations and basic statistics for variables in section 5a

	logRnD	DG	FG1	FG2	FG3	FG4	loggdptot	openn.	loggdpprc
logRnD	1								
DG	0.12	1							
FG1	0.15	-0.06	1						
FG2	0.13	0.13	0.72	1					
FG3	0	-0.18	0.15	0.11	1				
FG4	0.14	0.03	0.77	0.89	0.08	1			
loggdptot	0.95	0.15	0.08	0.12	-0.01	0.11	1		
openness	-0.65	0.02	0.05	-0.04	0.23	0	-0.7	1	
loggdpprc	0.5	0.08	0.15	0.14	0.27	0.14	0.49	-0.21	1
Mean	22.1	34.4	36.04	37.03	44.67	36.55	26.9	58.1	9.93
St.Dev.	1.65	4.35	2.18	1.94	1.89	1.58	1.4	28.55	0.25
Min.	18.65	25.1	32.03	31.45	39.72	32.12	24.38	16.31	9.3
Max.	25.61	44.6	41.82	42.09	48.96	41.66	29.76	157	10.74

Note: See main text for definitions of variables

Table B4 - Correlations and basic statistics for variables in section 5b

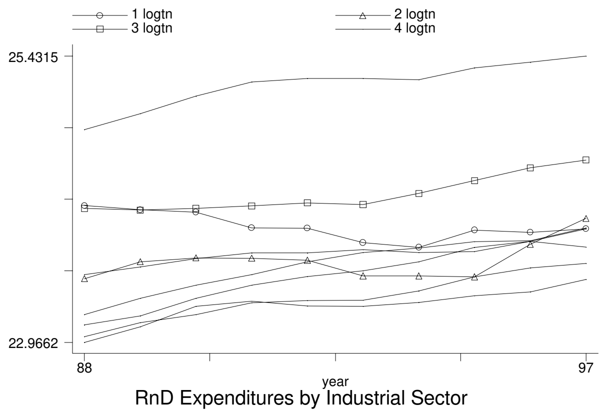
	loghtexpts	DG	FG	loggdptot	loggdpprc	relexchrate
loghtexpts	1					
DG	-0.09	1				
FG	0.71	0.13	1			
loggdptot	-0.27	-0.01	-0.18	1		
loggdpprc	0.6	0.21	0.53	-0.54	1	
relexchrate	-0.25	0.06	-0.1	0	0.05	1
Mean	22.03	45.98	38.15	26.75	8.49	5,283.07
St.Dev.	1.65	7.48	2.54	1.08	0.7	28,548.18
Minimum	18.49	33.64	33.14	24.22	7.17	0
Maximum	24.82	60.14	44.07	29.05	9.93	261,000

Note: See main text for definitions of variables

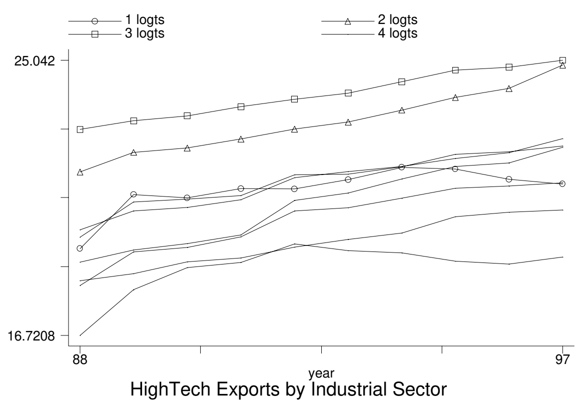
These tables convey the following information: correlation coefficients between the independent variables of sections 3 and 4 are high and may hint at a multicollinearity problem. The addition of control variables seems to make the problem worse. Notice however that there seems to be no multicollinearity problem in sections 5a and 5b which are characterized by much lower correlation coefficients. This is good news for the main findings of this study, since they are mainly based on section 5.

From Section 3 the following graphs are of some interest because they allow comparison of RnD expenditures and high tech exports across sectors:

Graph B1 (from Section 4):

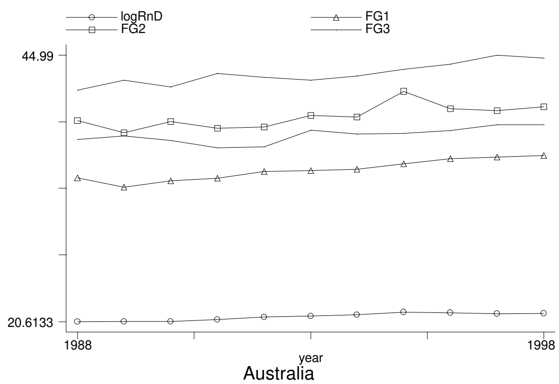


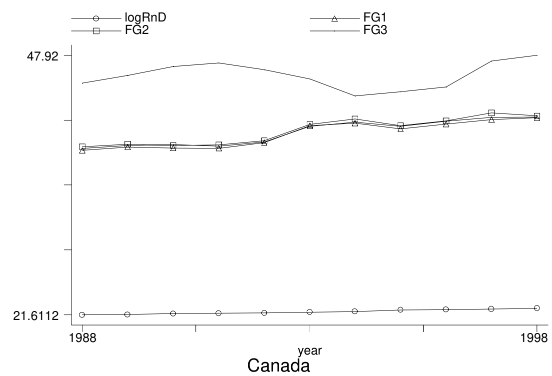
Graph B2 (from Section 4):

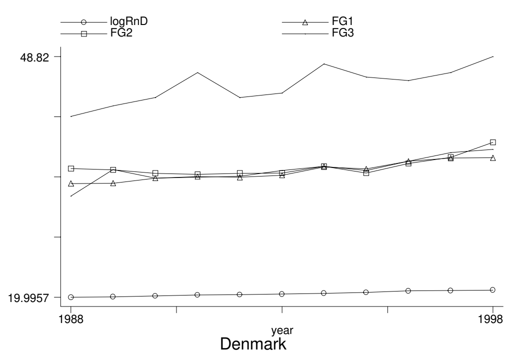


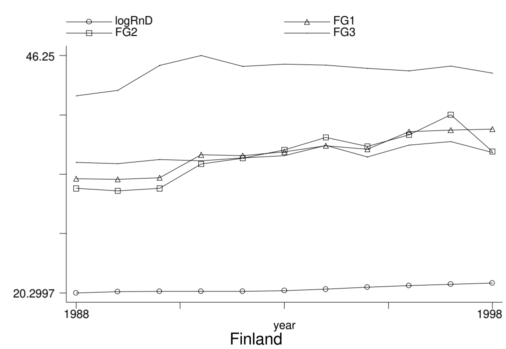
Graphs below display time series data, from 1988 to 1998, of logRnD expenditures (the lowermost line in the graphs), FG1, FG2, FG3 (the uppermost line in the graphs) and FG4 for each of the 15 OECD countries sampled.

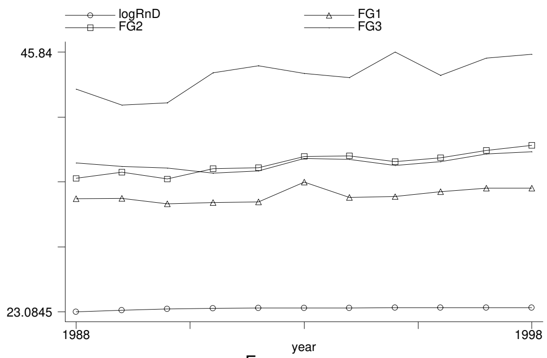
Graphs B3 to B17:



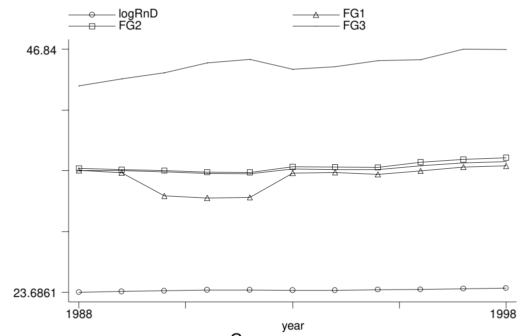




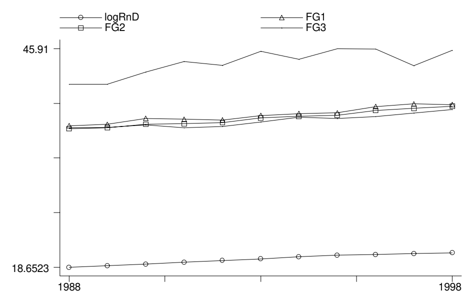




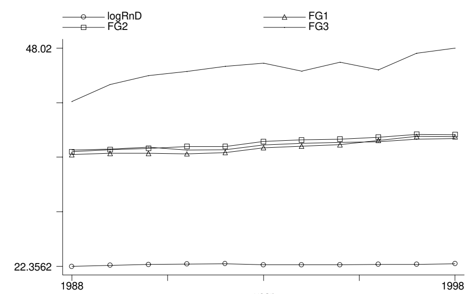
France



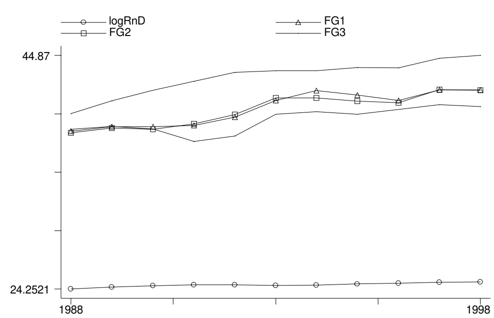
Germany



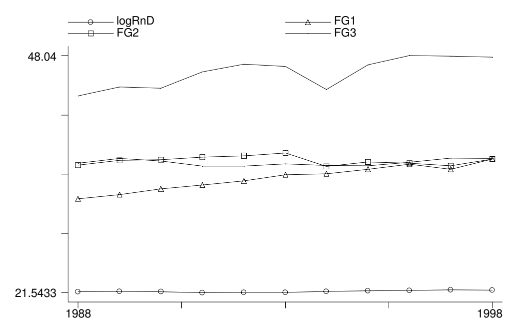
Ireland



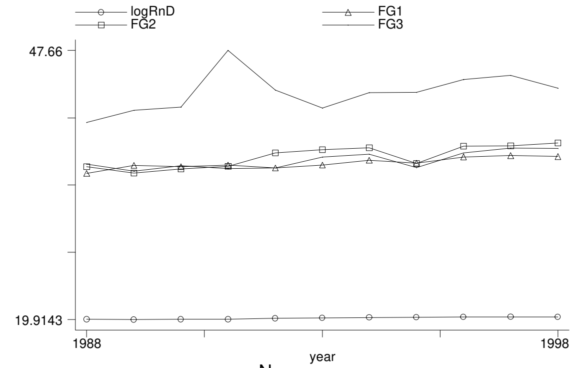
Italy



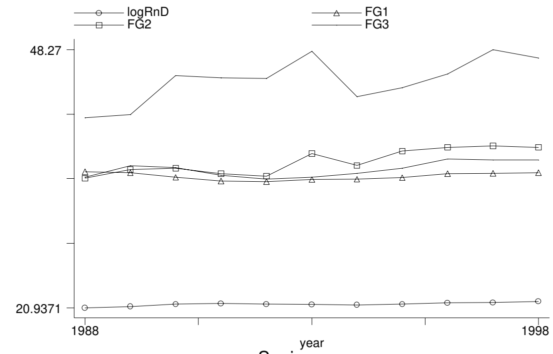
Japan



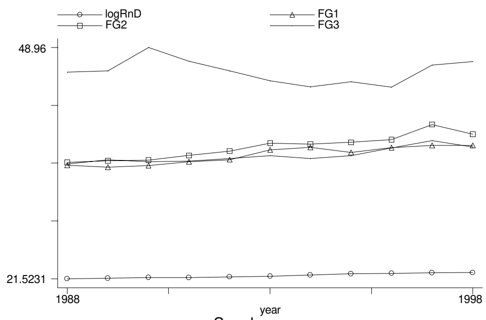
Netherlands



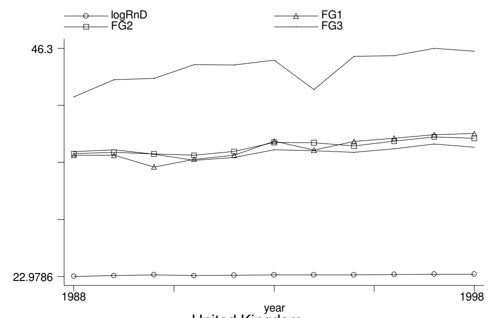
Norway



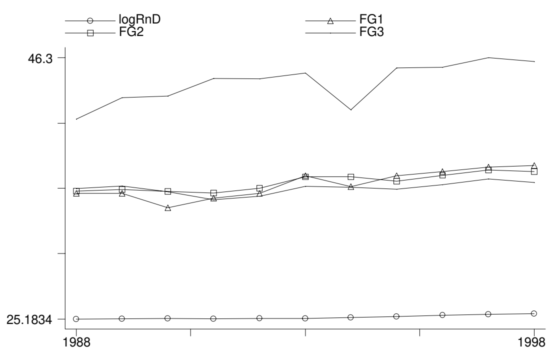
Spain



Sweden



United Kingdom



United States

The above graphs illustrate visually how different are the trade-weighted foreign Gini coefficients. It is apparent from the graphs that, with the exception of Australia and possibly France, the Netherlands for the first five years, and Spain for the last five years, in the remaining cases FG1, FG2 and FG4 are very similar measures of income inequality.