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Abstract

In this paper, we analyze the statistical properties of a large sample of trade openness series in the Second Era of Globalization (from 1948 to the recent crisis) and find a clear stationary pattern for developing countries versus a unit root pattern for developed countries. Most interestingly, we show how the progress of vertical specialization can rationalize this presence of unit roots in the ratio of export to GDP. We use scattered data of vertical specialization (defined as the imported input content of exports) for ten OECD countries to construct yearly export series free from the upwards bias introduced by vertically specialised trade in the official values. We find that when the statistical analysis is applied to the unbiased series of openness, they become trend stationary for nearly all the countries, corroborating the responsibility of vertical specialization in the presence of unit roots.

Key Words: Vertical Specialization; Unit Roots; Multi-accounting bias, Degree of Development

JEL: C22, F15

I. Introduction

In the last decade, there has been a large increase in the academic literature on the change in the nature of international trade. Unlike the horizontal specialization (specialization in goods) that dominated the *First Era of Globalization* (1870-1913), the *Second Era of Globalization* (from 1948 until the present crisis) has been characterized by vertical specialization (specialization in stages of the production process).

Feenstra (1998) has referred to this change as the disintegration of production in the global economy[1]. During the *Second Globalization*, and especially since the 1970's, the trade share of GDP has risen worldwide and, apart from the standard factors (income convergence, tariffs and transport-cost reductions), Feenstra (1998) mentions the need to consider the international disintegration of the production processes to explain this very considerable growth. According to this author, the disintegration of production means that inputs cross borders several times during the productive process, which introduces an upward bias into the openness ratio, because the numerator is gross value (in the export statistics) while the denominator is value-added (GDP). This upward bias has also been the main explanation given by Baier and Bergstrand (2001) in a much-cited article where, after carrying out a gravity equation analysis, they find that income convergence and reductions in tariffs and transport costs only explain 40 per cent of the world trade growth in 1958-1988[2]. Due to this vertically specialized

[1] Other terms to refer to the fragmentation phenomenon have been "slicing up the value chain" [Krugman, 1996], "delocalization" [Leamer, 1996], "outsourcing" [Feenstra and Hanson, 1996], "international production sharing" [Feenstra, 1998 and Yeats, 2001], "offshoring" [Arndt and Kierzkowski, 2001], "multi-stage production" [Dixit and Grossman, 1982], "vertical specialization" [Hummels *et al*, 1998], "kaleidoscope comparative advantage" [Bhagwati and Dehejia, 1994], "intra-product specialization" [Arndt, 1997], "intra-dediate trade" [Antweiler and Trefler, 1997], "vertical production networks" [Hanson *et al*. 2005], "production relocation" and "international segmentation of production" [Jones and Kierzkowski, 2001].

[2] Moreover, the bias is used to explain, as in Chen *et al*. (2005), that the goods export share rises while that of services declines, even though the manufacturing share of GDP declines and that of services increases in developed countries. The fact that a value-added criterion is applied to services, instead of a

trade, according to the last World Trade Report [World Trade Organization, 2009], the slump of the world openness in the present recession is greater than that registered in past slow-downs.

The goal of this paper is to show how the progress of vertical specialization, together with the above mentioned multiple-accounting bias, has been the cause of the presence of unit roots in international trade series (exports to GDP) until the outbreak of the current crisis. So far, very little attention has been paid to the study of the statistical properties of these series. While the volume of literature for the study of the integration order of some macroeconomic series is enormous[3], there are only two works whose goal is the study of trade (import, export and openness) series. One of them is Ben-David and Papell's (1997) article, where the authors analyze, for a large number of countries, whether the behaviour of the international trade shares of GDP changed gradually or not in the second half of the past century. The second article is that of Serrano *et al.* (2008), where the authors study the statistical properties of the Spanish openness series in the very long run (1870-2000).

However, neither of these works deals with vertical specialization and its potential effects on the international trade series, on which we focus our analysis. More specifically, we try to explain the puzzle of finding unit roots for most of the series of openness in the second half of the twentieth century [Ben-David and Papell, 1997], by relating this non-stationarity to the increase of the disintegration of production in the global economy. We call it a puzzle because the presence of unit roots is not consistent

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gross value, explains the relatively slower advance of their export share compared with that of manufacturing trade.

[3] In a seminal article, Nelson and Plosser (1982) studied the integration order of fourteen macroeconomic series, among them, real, nominal and per capita real GNP, unemployment, prices and interest rates. The same series have been studied in many other works [for instance, Perron, 1989; Zivot and Andrews, 1992; Lumsdaine and Papell, 1997; Lee and Strazicich, 2003]. Among the works analysing the properties of GDP and GNP, we can highlight Perron (1989), Stock and Watson (1988), Kormendi and Meguire (1990), Ben-David and Papell (1995, 1998), McCoskey and Kao (1998), Phillips and Moon (2000), Kapetanios (2002) and Carrión-i-Silvestre et al. (2005).

with the analysis of bounded variables which, in theory, the ratio of exports over GDP is. Our hypothesis is that, if unit roots are not simply masking the existence of structural breaks, they might be reflecting the upward bias introduced by the vertical specialization into the openness series, as a consequence of which the export shares of GDP do not necessarily have to be bounded between 0 and 1.

To support this hypothesis, we start by carrying out an analysis of the statistical properties of the series of exports over GDP for 54 countries in 1948-2005. When applying time series analysis, in accordance with the results of Ben-David and Papell (1997), we find an overwhelming presence of unit roots in the ratios. However, if we consider the possibility of breaks, while most of the Less Developed Countries' (LDC) series become stationary, non-stationarity continues to affect more than half of the Developed Countries' (DC) series. Most interestingly, when applying a panel analysis with structural changes, a clear pattern of unit roots for DC versus stationarity for LDC emerges. The whole sample shows evidence of stationarity, but when dividing the panel according to the degree of development, we find that the rejection of non stationarity only remains for the LDC group. Thus, the finding is fully consistent with the theory of the disintegration of production, which assigns a major role to the decline of trade costs in the process and predicts difficulties for these LDC to join the international network. Poorer infrastructure and institutional frameworks hinder the entrance of LDC into the network, so their series are not necessarily affected by the multi-accounting bias that vertical specialization introduces into the openness ratios. Meanwhile, the non-stationarity in the openness series of DC might be related to the advance of vertical specialization and its consubstantial multi-accounting bias.

The next step is to relate the presence of unit roots and vertical specialization in the DC for which we have available data. We have scattered data of vertical

specialization (as the percentage of imports embodied in domestic exports) for about five different years between 1968 and 1998 in ten OECD countries. We use this information, provided by Hummels *et al.* (2001) and Chen *et al.* (2005), to obtain a new measure of openness free from the bias introduced by the vertical specialization for each available year. Then, by interpolating data into this new measure, we generate ten yearly series, which we assume are representative of the evolution of the export value actually added in each country between 1948 and 2005. Finally, we apply unit root tests to the unbiased openness series and find that, as expected, the results change substantially from those obtained with the original series. Once the multiple-accounting effect of the vertical specialization is taken into account, the export share of output becomes stationary for nine out of the ten countries, in contrast to the results obtained for the original openness series, where only three countries out of the ten exhibited a stationary trend.

In sum, this paper contributes to illustrating the different statistical properties of openness series in the *Second Era of Globalization*, depending on the degree of development of the countries. We find a clear pattern of stationarity for LDC versus a pattern of unit roots for DC. Most importantly, the paper relates the predominance of unit roots in DC to the advance of vertical specialization in recent decades. As a result, by considering the upward bias introduced by vertical specialization into the official gross-valued export series, the paper rationalizes the econometric puzzle of typifying external openness as unit root series when openness, as a ratio, is supposed to be a bounded variable.

The rest of the paper is organised as follows. Section II summarises some stylised facts related to the international disintegration of production. Section III analyses the statistical properties of the series of openness in the *Second Era of*

Globalization (1948-2005) for a sample of 54 countries, by applying time series and panel data analysis. Section IV presents the unbiased openness series we construct for ten OECD countries. It also contrasts the different properties of the original series and the modified ratios of openness, having removed the multi-accounting induced by vertical specialization. Finally, Section V concludes.

II. The advance of vertical specialization

In recent years, a consensus has been reached about the new nature of international trade. Current productive processes have come a long way from the horizontal specialization of the *First Era of Globalization* [O'Rourke and Findlay, 2003]. In the last four decades, a new international trade has arisen as a consequence of the vast fragmentation in the productive processes[4]. The new international trade in the *Second Era of Globalization* not only involves the exchange of entire products, but also an increasing trade in intermediate inputs, so companies compete in final products as well as in unfinished products. While the *First Globalization* allowed the spatial separation of factories and consumers, the *Second Globalization* has divided up the factories themselves [Baldwin, 2006].

On the theory side, the failure of traditional international trade models, and even monopolistic competition models, to explain this very new trade behaviour has generated a flourishing literature about the new circumstances in production and trade. The first theoretical works started by introducing intermediate goods in Heckscher-Ohlin type models, as in Brata and Casas (1973) and Dixit and Grossman (1982). In a second round, following the much-cited work of Jones and Kierzkowski (1990), a

[4] The term "fragmentation" was proposed by the international trade theorists Jones and Kierzkowski (1990).

rapidly growing literature proposed different mathematic models that, also in a Heckscher-Ohlin setting, explain the advance of the international fragmentation and its consequences in terms of prices, wages and production [Venables,1999; Deardorff 2001a, b, 2005; and Yi, 2003, among others][5]. More recently, Grossman and Rossi-Hansberg (2006a, b; 2008) have moved away from the traditional international goods trade approach and modelled what they call *task trade*, that is to say, the specialization of a country not in goods but in stages of production. Finally, Baldwin and Robert-Nicoud (2007) propose a model to explain the consequences of trading in tasks, which is also applied in a monopolistic competition setting.

In any case, whatever the approach, the decision to outsource abroad always requires the cost savings of disintegrating different stages of production to be higher than the costs associated with the spatial fragmentation. The advance of vertical specialization would not have been feasible without a sustained reduction in the special fragmentation-related costs, also generally referred to as trade costs. There is direct evidence, in the second half of the twentieth century, of a worldwide downward trend in tariff barriers[6]. With respect to non-trade barriers, the elimination of Voluntary Exports Restrictions (VERs), the disappearance of the Multi-Fibre Agreement (MFA) and the phasing-out of agricultural quotas in developed countries confirm the idea that the downward trend also applies to them. As regards transport costs, a number of works [Hummels, 1999, 2001, 2007] have documented a noticeable reduction in the transport times of long-haul air freights (since WWII) and of maritime shipping (mostly due to the use of containers in the seventies[7]). Moreover, the time spent in administrative and

[5] See Baldwin and Robert-Nicoud (2007) for a recent review of models of international disintegration/fragmentation

[6] See Anderson and van Wincoop (2004) for a comprehensive discussion on the measurement problems and trends in tariff, non-tariff and other trade barriers, including transport costs.

[7] Hummels (2001) estimates that the combined time reductions in air and maritime transport was equivalent to a fall in the tariff on manufactures from 32 to 9 % in 1950-1998.

certification procedures has also undergone an important decrease which, added to the time saved in the transportation process, has led to a significant reduction in the need for storage and the associated costs. Finally, there is no need to emphasize how technological progress has eased communication across countries in recent decades and, by dropping its cost to almost zero, has spectacularly reduced the efforts necessary to find suppliers abroad. The overall decline in these costs is behind the phenomenon of international fragmentation, whose advance in recent decades can be traced with the help of different measures.

The literature suggests different data sources to quantify the phenomenon of international fragmentation, among them, international trade statistics on parts and components and Input-Output tables[8]. A first rough measure of the advance of the process can be proxied by the performance of trade on parts and components. In the nineties, this kind of trade grew much faster than the total world trade, even faster than the intra-industry trade [Jones, Kierzkowsky and Lurong, 2005], and despite the slow-down of recent years, data document a more dynamic performance of trade in intermediate inputs than trade in final goods during 1988-2006 [World Trade Organization, 2008][9].

The same advance of international fragmentation can be inferred from two more accurate measures of external orientation based on Input-Output information. The first measure concentrates on the foreign content of domestic production by using the index share of direct imported inputs in production or in total inputs. It was developed by Feenstra and Hanson (1996) and has been widely used to assess the consequences of fragmentation on wages and employment, as in Egger and Egger (2003), Bardhan and

[8] See Bauman and di Mauro (2007) for a wide review about different methods and data, and Amador and Cabral (2008) for a review of the three main different data sources and methods used by the empirical trade literature to quantify the fragmentation phenomenon.
[9] Yeats (2001), although restricted to the machinery sector, goes back further and provides evidence of the advance of trade on parts and components in the OECD countries from 1978 to 1995.

Kroll (2003), Wei (2004), Hijzen (2005) and Geishercker *et al.* (2008)[10]. This measure has also been used to assess the degree of external orientation by Campa and Goldberg (1997) who, focusing on U.S., U.K., Canada and Japan, observe an increase in imported inputs into production for all countries except Japan. One more example is Feenstra (1998), who presents results for the whole manufacturing sector and several disaggregated industries across a wider range of developed countries. This measure also provides evidence that international fragmentation has progressed recently, as the world percentage of imported intermediate inputs over total inputs has increased from 18.8 to 22 between 1995 and 2000 [World Trade Organization, 2008].

The second type of Input-Output measure focuses on the foreign content of exports. Whereas the first measure only captures the direct import content of exports (imported intermediate inputs), the second measure reflects the direct and indirect import content of exports. This second measure is proposed by Hummels *et al*. (1998) and Hummels *et al*. (2001), who labelled it vertical specialization (VS)[11]. In comparison with the first Input-Output measure, Hummels *et al.*'s (2001) vertical specialization measure is narrower, because it only considers the imported inputs embodied in the exported output. Nevertheless, it is the best measure to approach the change in the nature of international trade that we are interested in.

This measure of VS is defined as the importation of intermediate goods used by a country to make goods or goods in process, which are in turn, exported to another country. So, three conditions have to hold for VS to occur. Firstly, the good has to be produced in at least two sequential stages. Secondly, two or more countries have to add value during the productive process and, finally, the country that uses the imported

[10] See Horgos (2007) for a detailed analysis of this index.
[11] Originally, the term vertical specialization was used by Balassa (1967) to refer to the process according to which, to take advantage of market size and scale economies, manufacturing parts, components, and accessories were produced in separate establishments.

inputs must export some of the resulting output. Therefore, vertical specialization offers a complete perspective of the changed nature of international trade since it captures, on the import side, the essence of international outsourcing (the decision of firms to substitute domestic value added through the import of intermediate goods) and, on the export side, the trading of either intermediate or final goods.

Analytically, the Vertically Specialized trade is defined for sector *i* as:

$$VS_i = \left(\frac{IIM}{gross\ \ output} \right) * X$$

where *IIM* denotes the value of Imported Intermediate Inputs in sector *i*, and *X* represents the merchandise exports.

Thus, the *VS* trade for country *k* is the sum of VS_i across all sectors:

$$VS_k = \sum_i VS_{ki} = \sum_i \left(\frac{IIM_{ki}}{gross\ \ output_{ki}} \right) * X_k$$

and the measure given by Hummels *et al*. (2001) is the *VS* trade share of X:

$$\frac{VS_k}{X_k} = \frac{\sum_i VS_{ki}}{\sum_i X_{ki}} .$$

They estimate *VS* for ten developed countries and four developing countries between 1970 and 1990 and find that it accounts for more than 20% of exports and explains 30% of the growth in the overall export/GDP. The World Trade Organization's (2008) calculations for a sample of 28 countries confirm that *VS* (ranging from 14 to 60%) has continued to advance and accounts for an important share of export growth in the period 1995-2000. The following sections look for the effects of this international fragmentation process on the statistical properties of the external openness series.

III. Stochastic properties of the international trade series

We work with a set of 54 economies from 1948 to 2005, which includes two sub-samples, one of 32 Less Developed Countries (LDC) and the other of 22 Developed Countries (DC), according to the World Bank criteria. Yearly data on exports, GDPs and exchange rates come from the International Financial Statistics of the International Monetary Found (2007). We work with nominal terms of GDP and exports, the latter being converted into national currency by using the annual average of the official or market exchange rates, depending on the country.

a. Exploiting time variation

We start the analysis of the integration order of the openness series by applying the Augmented Dickey and Fuller (1979, 1981) (ADF) and the Ng and Perron (2001) (NP) unit root tests, and the stationarity test of Kwiatkowski *et al*. (1992) (KPSS)[12]. The results show that, according to the unit root tests, almost all the series have a unit root, whereas the opposite is found when applying the KPSS test. The contradiction between the unit root and stationarity tests might be a symptom of the presence of structural changes in the series, which in turn, would fit in with the break found by Ben-David and Papell (1997) in their international trade series**,** according to Vogelsang's (1997) test.

Thus, taking into account the outcomes obtained by Ben-David and Papell (1997), we consider the possibility that, in the second half of the twentieth century, the market integration prompted by trade liberalization and a decrease in transport costs,

[12] To select the correct order of the autoregressive process in the ADF and NP tests, we use the Modified Akaike Information Criterion. We use the MZGLS statistic (AR spectral – GLS detrending) of the unit root test developed by NP. The KPSS test has been modified by using the spectral estimation window proposed by Sul *et al*. (2003), since Carrión-i-Silvestre and Sansó (2005) demonstrated that, if it is used to estimate the long-run variance, the KPSS test shows a smaller size distortion and a satisfactory power. Tables are available on request

caused breaks in the X/GDP ratios. We test for the presence of breaks in the series by using the new method proposed by Perron and Yabu (2008)[13], as a pre-test to obtain certain information on the existence or not of structural changes in the series. This test, that considers the three traditional models (A,B and C) proposed in Perron (1989)[14], is able to detect the presence of one structural break in the trend function without any prior knowledge as to whether the noise component is stationary or contains an autoregressive unit root. When this test is applied to our data, we find that there is at least one significant structural break in most of the series. The results, in Table 1, show a strong rejection of the null of a stable trend function in favour of a trend function with a shift in forty countries out of fifty four. Six of the fourteen countries without a structural change are LDC and eight DC. Thus, in relative terms, there is more evidence of stability in the trend function for developed countries.

Following to Perron (1989), the next step is to test again for a unit root, but with a test that allows for the presence of structural changes. We use the test developed by Lee and Strazicich (LS) (2004) that considers the presence of one structural break in the series under both the null hypothesis of a unit root and the alternative hypothesis of stationarity. These authors showed the negative consequences of considering structural breaks only under the alternative hypothesis in unit root tests[15] and, trying to avoid these problems, developed a new LM type test that determines the break points endogenously[16]. So, with the LS test, the rejection of the null hypothesis unambiguously implies that the series are trend stationary.

[13] This test improves the finite sample properties by using the bias corrected version of the OLS estimate of α proposed by Roy and Fuller (2001). It is also more powerful than Vogelsang' s (1997) test largely used in the empirical literature.

[14] That is, model A (the "crash" model), that permits a change in the levels of the series; model B, that permits a change in the rate of growth; and model C, that allows both changes.

[15] As occurs in Zivot and Andrews (1992), Perron (1997), Lumsdaine and Papell (1997) and Vogelsang and Perron (1998), among others.

[16] Lee and Strazicich (2003) show that, if we do not consider breaks under the null in tests with endogenous breaks, the test statistics may diverge and lead to a rejection of the null when the DGP is

TABLE 1.—Analysis of Structural Change. Perron and Yabu (2008)

	Developing Countries	Exp-W_{FS} [1]		Developed Countries	Exp-W_{FS} [1]
1	Algeria	12.47489 [b]	1	Australia	91.90455 [b]
2	Barbados	1.02926	2	Austria	3.55738 [b]
3	Colombia	2.19358	3	Canada	1.1568
4	Congo, Rep.	4.09633 [b]	4	Denmark	2.11751 [b]
5	Costa Rica	19.81272 [b]	5	Finland	0.88589
6	Cyprus	7.06194 [b]	6	France	1.14495
7	Dominican, Rep.	1.44693	7	Germany	6.766 [b]
8	Egypt	5.48717 [b]	8	Greece	4.5408 [b]
9	El Salvador	13.39325 [b]	9	Iceland	11.88411 [b]
10	Fiji	0.87336	10	Ireland	8.50329 [b]
11	Guatemala	4.01152 [b]	11	Italy	1.15126
12	Guyana	5.95367 [b]	12	Japan	3.65051 [b]
13	Haiti	2.45393 [b]	13	Korea, Rep.	8.32728 [b]
14	Honduras	4.72385 [b]	14	Netherlands	17.22745 [b]
15	India	2.3889	15	New Zeeland	8.51407 [b]
16	Jamaica	17.11131 [b]	16	Norway	2.59666
17	Mali	8.93994 [b]	17	Portugal	20.22143 [b]
18	Malta	4.8154 [b]	18	Spain	2.46568 [b]
19	Mauritius	2.57125 [b]	19	Sweden	1.01961
20	Mexico	26.50599 [b]	20	Switzerland	1.50549
21	Morocco	3.67226 [b]	21	United Kingdom	1.66018 [c]
22	Nigeria	13.41796 [b]	22	United States	0.86151
23	Pakistan	8.92512 [b]			
24	Panama	6.21344 [b]			
25	Paraguay	15.57105 [b]			
26	Philippines	100.5456 [b]			
27	South Africa	1.62728 [c]			
28	Sri Lanka	17.31538 [b]			
29	Sudan	16.7434 [b]			
30	Thailand	5.9129 [b]			
31	Trinidad y Tobago	18.55183 [b]			
32	Venezuela	1.14358			

[1] Critical values are provided in Perron and Yabu (2008)

a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively

Models A, B and C [Perron 1989] represent changes in levels, trend and both levels and trend together, respectively

Source: own elaboration.

integrated with structural breaks, as in the Lumsdaine and Papell (1997) test. In addition, these approaches, derived by assuming no structural breaks under the null, might present problems in empirical applications because the rejection of the null does not necessarily imply the rejection of a unit root *per se*, but may imply the rejection of a unit root without breaks. Similarly, the alternative hypothesis does not necessarily imply trend stationarity with breaks, but may indicate a unit root with breaks. For a complete description of the test, see Lee and Strazicich (2003 and 2004).

LS (2004) propose two of the three above mentioned structural break models considered in Perron (1989), A and C, to simulate the Data Generating Process (DGP)[17], based on the unobserved components model:

$$y_t = \delta' Z_t + \beta X_{t-1} + \varepsilon_t,$$

where Z_t includes exogenous variables, the unit root null hypothesis is described by $\beta = 1$ and $\varepsilon_t \sim iidN(0, \sigma^2)$. For Model A, which allows for one break in the intercept, $Z_t = [1, t, D_t]'$, where $D_t = 1$ for $t \geq T_B + 1$, and 0 otherwise. T_B is the break year and $\delta' = (\delta_1, \delta_2)$. For Model C, that allows for a change in the intercept and in the trend slope, $Z_t = [1, t, D_t, DT_t]'$, where $DT_t = t - T_B$ for $t \geq T_B + 1$ and 0 otherwise[18]. To correct the auto-correlated errors, we have included augmented terms following the general-to-specific procedure described in Perron (1989) and suggested in Ng and Perron (1995) to determine the optimal number of lags (p)[19]. Once the test statistic has been obtained, the location of the break (T_B) is determined by calculating the unit root test *t*-test statistic in all the possible break points and then, selecting the one for which the test statistic is minimized[20]. Finally, to choose between models A and C, we use the information criteria of Akaike (AIC) and Swartz (SBIC).

Following these econometric advances, we show that, once one break is taken into account, 26 out of the 40 countries with structural change, become trend stationary. More interestingly, we find a clear difference between LDC and DC. While more than seventy percent of countries in the first group (19 out of 26) become trend stationary,

[17] They omit Model B, without any risk of losing generality, as it is commonly held that most economic time series can be adequately described by models A or C.
[18] See LS for a detailed explanation about how to construct the break LM unit root test.
[19] We begin with a maximum number of lagged first-differenced terms *p*= 4, obtained from the formula $\sqrt[3]{T}$. This technique has been shown to perform well as compared to other data-dependent procedures to select the number of augmented terms in unit root tests [Ng and Perron, 1995].
[20] We select a t*rimming* of 10%.

only fifty per cent (7 out of 14) do so stationary in the second[21]. However, before drawing any conclusions on this finding, we consider the warning of Perron (1989) about the loss of power of tests when ignoring a break and continue the analysis looking for a second one. So, we apply the LS (2003) test, which, in the same line as LS (2004) for one break, allows for the presence of two breaks under the null and the alternative hypotheses. Analogously, model A allows two changes in levels $Z_t = [1, t, D_{1t}, D_{2t}]'$, D_{jt} being a *dummy* variable equal to 1 if $t \geq T_{B_j} + 1, j = 1,2$ and 0 otherwise, where T_{B_j} is a break year. Model C allows two changes, in both levels and trend, so that $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where $DT_{jt} = t - T_{B_j}$ if $t \geq T_{B_j} + 1, j = 1,2$ and 0 otherwise.

Thus, the null and alternative hypotheses in model A are:

$$H_0 : y_t = \mu_0 + d_1 B_{1t} + d_2 B_{2t} + y_{t-1} + \upsilon_{1t},$$

$$H_1 : y_t = \mu_1 + \gamma t + d_1 D_{1t} + d_2 D_{2t} + \upsilon_{2t},$$

where υ_{1t} and υ_{2t} are stationary error terms, and $B_{jt} = 1$ if $t = T_{Bj} + 1, j = 1,2$ and 0 otherwise[22]. Analogous argument can be applied to model C for both hypotheses:

$$H_0 : y_t = \mu_0 + d_1 B_{1t} + d_2 B_{2t} + d_3 D_{1t} + d_4 D_{2t} + y_{t-1} + \upsilon_{1t}$$

$$H_1 : y_t = \mu_1 + \gamma t + d_1 D_{1t} + d_2 D_{2t} + DT_{1t} + DT_{2t} + \upsilon_{2t}$$

Proceeding as in LS (2004), the endogenous two-break LM unit root test shows that the outcomes barely change if they are compared with those resulting from the consideration of one break. Only the openness series of one LDC becomes stationary when considering two breaks. The results of this analysis are presented in Tables 2 and

[21] If we include Barbados, Colombia and Sweden, without breaks according Perron and Yabu (2008), in the test of LS (2004) they also have a stationary trend.

[22] The H_0 includes the *dummy variable* B_{jt} so it is necessary to ensure that the asymptotic distribution of the test statistic is invariant to the size of breaks (d) under the null [Perron, 1989].

3, together with those obtained by applying unit root tests without breaks *MZGLS* [Ng and Perron, 2001] and the unit root test with one structural break LM_τ [LS, 2004]. We find an overwhelming presence of unit roots in the LDC (30 countries out of 32) but most of them disappear when we consider breaks in the unit root test (only 10 countries continue to show unit roots). The results for the DC again show a predominance of unit roots (20 out of 22) when we do not take structural breaks into account, but when we allow for breaks, although the presence of unit roots diminishes (13 countries maintain the unit roots), it does not do so to such an extent as in the LDC. In sum, we observe that the overwhelming presence of unit roots in the DC seems not to be a consequence of structural breaks; 60% of the openness series maintain their non-stationarity after the break analysis. Conversely, in the LDC, only 30% of the series show unit roots when we allow for structural changes.

b. Exploiting time and cross-country variations

In the analysis of the sample of 54 countries (1948-2005), we use the stationarity test with structural changes developed by Carrion-i-Silvestre *et al*. (2005). This test allows for multiple structural breaks that can differ in time, intensity and location across individuals[23]. We test the null hypothesis of panel stationarity with multiple structural breaks against the alternative of first order integrated, since some authors have proposed using the two types of tests (unit root and stationarity tests) to carry out a sort of confirmatory analysis[24].

[23] The seminal contributions to the analysis of unit roots in a panel framework are from Quah (1994), Phillips and Moon (1999) and Levin *et al*. (2002). However, while several tests have been proposed, less attention has been paid to the presence of temporal structural changes in panel data analysis. Exceptions are the well-known papers of Carrion-i-Silvestre *et al*. (2002), Im *et al*. (2005) and Carrion-i-Silvestre *et al*. (2005), among others.

[24] See Maddala and Kim (1998) for a summary.

TABLE 2.—X/GDP. Analysis of Unit Root: Less Developed Countries

	Country	Stat.[1]	Model [2]	Break year
1	Algeria	-3.403 [c]	A	1985
2	Barbados	-2.5919	-	-
3	Colombia	-2.1842	-	-
4	Congo, Rep.	-4.743	C	1974-1990
5	Costa Rica	-4.1783 [b]	A	1955
6	Cyprus	-4.5396 [b]	C	1978
7	Dominican, Rep.	-2.8673 [c]	-	-
8	Egypt	-5.0408 [b]	C	1991
9	El Salvador	-5.9613 [b]	C	1978-1988
10	Fiji	-2.1491	-	-
11	Guatemala	-4.7868 [b]	C	1968
12	Guyana	-4.6861	C	1979-1991
13	Haiti	-4.6222	C	1975-1994
14	Honduras	-4.8332	C	1976-1989
15	India	-0.7015	-	-
16	Jamaica	-4.9211 [b]	C	1995
17	Mali	-5.3554	C	1965-1985
18	Malta	-4.7592 [b]	C	1971
19	Mauritius	-4.6574 [b]	C	1985
20	Mexico	-4.4133 [c]	C	1975
21	Morocco	-4.223 [b]	A	1993
22	Nigeria	-3.4804 [c]	A	1986
23	Pakistan	-4.5365 [b]	C	1975
24	Panama	-4.523	C	1974-1985
25	Paraguay	-4.8296 [b]	C	1977
26	Philippines	-9.9627 [a]	C	1996
27	South Africa	-4.7183 [b]	C	1976
28	Sri Lanka	-4.4595 [c]	C	1975
29	Sudan	-4.853 [b]	C	1986
30	Thailand	-4.431	C	1965-1995
31	Trinidad y Tobago	-4.4708 [c]	C	1980
32	Venezuela	-3.5290 [a]	-	-

a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively.

We apply the general-to-specific procedure, described in Ng and Perron (1995), to select the number of lags with a kmax equal to

[1] Represents either t-statistics of MZGLS [Ng and Perron, 2001], LMτ [LS, 2004] or LMτ [LS, 2003] depending on whether exist 0, 1 or 2 structural breaks respectively in the series.

[2] Model A: break in levels. Model C: break in both levels and trend. [Perron 1989]

Source: own elaboration.

The test proposed by Carrion-i-Silvestre *et al*. (2005) is based on the KPSS panel data version developed by Hadri (2000) and generalizes existing proposals in the

field. The null hypothesis implies stationarity so there has to be strong evidence against trend stationarity to conclude in favour of the non-stationarity of the panel. The test is

TABLE 3.—X/GDP. Analysis of Unit Root: Developed Countries

	Country	Stat.[1]	Model [2]	Break year
1	Australia	-5.3551 [a]	C	1960
2	Austria	-5.0199	C	1959-1997
3	Canada	-1.9371	-	-
4	Denmark	-4.9987	C	1955-1968
5	Finland	-2.3346 [b]	-	-
6	France	-2.2339	-	-
7	Germany	-4.6289 [b]	C	1989
8	Greece	-5.0984	C	1958-1984
9	Iceland	-5.534 [a]	C	1958
10	Ireland	-4.289 [c]	C	1992
11	Italy	-2.0223	-	-
12	Japan	-3.8189	C	1985
13	Korea, Rep.	-4.9441	C	1971-1989
14	Netherlands	-4.9328	C	1978-1990
15	New Zeeland	-5.516 [a]	C	1975
16	Norway	-3.0313 [b]	-	-
17	Portugal	-6.0608 [a]	C	1981
18	Spain	-4.4514	C	1963-1994
19	Sweden	-2.1979	-	-
20	Switzerland	-1.8438	-	-
21	United Kingdom	-3.4532 [c]	A	1973
22	United States	-2.2039	-	-

a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively.
We apply the general-to-specific procedure, described in Ng and Perron (1995), to select the number of lags with a kmax equal to
[1] Represents either t-statistics of MZGLS [Ng and Perron, 2001], LMτ [LS, 2004] or LMτ [LS, 2003] depending on whether exist 0, 1 or 2 structural breaks respectively in the series.
[2] Model A: break in levels. Model C: break in both levels and trend. [Perron 1989]

Source: own elaboration.

normally distributed and shows a good finite sample performance, as well as allowing the inclusion of individual fixed effects and/or a specific individual time trend.

More specifically, the null hypothesis is equivalent to considering $\sigma_{v,i}^2 = 0, \forall i = 1,..., N$, where $\sigma_{v,i}^2$ is the variance of the error that includes the individual effects in the data generating process (DGP):

$$y_{i,t} = \alpha_{i,t} + \beta_i t + \varepsilon_{i,t}$$

Under the null, the model becomes:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{m_i} \theta_{i,k} DU_{i,k,t} + \beta_i t + \sum_{k=1}^{m_i} \gamma_{i,k} DT^*_{i,k,t} + \varepsilon_{i,t},$$

with the dummy variable being $DU_{i,k,t} = 1$ for $t > T^i_{b,k}$ and 0 elsewhere, and $T^i_{b,k}$ denoting the k^{th} date of the break for the i^{th} individual, $k = 1,...,m_i, m_i \geq 1$. The dummy is $DT^*_{i,k,t} = t - T^i_{b,k}$ for $t > T^i_{b,k}$ and 0 elsewhere, $k = 1,...,m_i, m_i \geq 1$. The model includes individual effects, individual effects with structural breaks[25], temporal effects ($\beta_i \neq 0$) and temporal effects with structural breaks[26] if $\gamma_{i,k} \neq 0$.

Two kinds of models are considered in the analysis. First, we consider Model 1 ($\beta_i = \gamma_{i,k} = 0$) [Perron and Vogelsang, 1992], without either time effects or structural breaks in the time trend. Model 2 ($\beta_i \neq \gamma_{i,k} \neq 0$) is the model C developed in Perron (1989) and allows a time trend and structural changes affecting either the trend or the level[27].

The procedure begins by detecting the structural changes of the individuals in the panel. Given a maximum number of break points (m^{max}), we estimate the position for each $m_i \leq m^{max}$, i = 1,…, N, and then test the significance of the breaks to obtain the optimum number and location for each series. To select the break date, we follow Bai and Perron (1998) in their criterion for locating the breaks using to the argument that minimizes the sequence of individual SSR $\left(T^i_{b,1},...,T^i_{b,m_i}\right)$:

$$\left(\hat{T}^i_{b,1},...,\hat{T}^i_{b,m_i}\right) = \arg\min_{T^i_{b,1},...,T^i_{b,m_i}} SSR(T^i_{b,1},...,T^i_{b,m_i}),$$

where the trimming applied locates the break point in the interval $[0.05T, 0.95T]$. To select the optimum number of breaks, we use the information criterion of LWZ

[25] Shifts in the mean caused by the structural breaks.
[26] Shifts in the individual time trend.
[27] The use of model C (Perron, 1989) lets us obtain homogeneous outcomes if we compare it with those of the time series analysis.

proposed in Bai and Perron (1998). We obtain a vector for each individual with the optimum number of breaks and, if we find an individual without breaks, we use the test without structural breaks. As we are working with trending variables, we assume a trend in the deterministic component[28]. The long-run variance estimate is obtained as described in Sul *et al*. (2003), with the specification of an $AR(p)$ process for the prewithening and using both the Bartlett and the Quadratic spectral window with automatic bandwidth selection [Andrews, 1991, Andrews and Monahan, 1992, Sul *et al*., 2003]. The order of the autoregressive process in the prewithening stage is fixed by using the BIC information criterion with a $p^{\max} = 4$ lags.

In practice, we set a maximum of two breaks to obtain comparable outcomes to those of the time series analysis. Then, we select the optimum number of breaks for each country with the LWZ information criterion[29]. The results, in Table 4, report the impossibility of rejecting the null hypothesis of stationarity in the whole panel at a significance level of 10%. In other words, the analysis shows evidence in favour of stationarity for the whole sample of X/GDP series. However, when repeating the analysis with the panel divided into two sub-panels, one for LDC and the other for DC, the results change substantially, in line with the outcomes in the previous time series analysis. We find strong evidence against stationarity in the panel for DC and evidence in favour of stationarity in the panel for LDC.

When exploiting jointly the time structure and the cross-sectional dimension of the data and, consequently, enhancing the power of tests, we obtain additional support for the idea that changes in international trade have not been affecting LDC and DC

[28] Carrion-i-Silvestre (2005).
[29] We work with a balanced panel from 1954 to 2004 for reasons of simplicity. We eliminate Algeria, Congo, Germany, Haiti, Malawi, Netherlands, Paraguay and Sudan from the panel due to the lack of data to construct the balanced panel.

TABLE 4.—X/GDP. Stationary panel data test

Panel A: Whole panel	
	Bartlet
	Estadístico (p-value)
Exports/GDP	1.837 (0.033)

Panel B: Sub-panels for LDC and DC	
	Bartlet
	Estadístico (p-value)
LDC	0.108 (0.457)
DC	6.168 (0.000)

The maximum numbre of break points allowed is two.

The long-run variance is estimeted assuming homogeneity.

Source: Own elaboration.

equally during the *Second Era of Globalization*. Our hypothesis is that the predominance of unit roots in the openness series of DC reflects their active role in the advance of international fragmentation, while the stationarity of the series of LDC mirrors their exclusion from the international production network. The reason is that, although international trade costs have plummeted, some important country-specific barriers (quality of port, airport and communication infrastructures, administrative requirements for imports and exports,…) remain comparatively high in LDC, thus hindering their connection to the international network [World Trade Organization, 2008].

IV. Marrying unit roots to vertical specialization

The analysis of the statistical properties of a number of series of export over GDP shows that the majority of those corresponding to DC are non stationary. This means that they can be modelled as the sum of a stochastic trend, the shifts registered each period and a non-permanent (transitory) term. In other words, any stochastic shock has a permanent effect on the process and there is no reversion to a deterministic trend

path. Ben-David and Papell (1997) had already accepted a difference stationary representation of the international trade series for a broad sample of countries in the second half of the twentieth century. What stands out in the literature is the absence of controversy over the integration order of the series that we are examining (export over GDP), unlike many macroeconomic variables.

If we take this variable as a fraction, we are assuming that is bounded in the [0, 1] interval. However, when working with bounded variables, the presence of unit roots is econometrically excluded because it implies that the long-run variance increases indefinitely over time. In other words, we are facing the puzzle of typifying external openness for developed countries as a unit root series when openness, as a fraction, is supposed to be a bounded variable. In order to solve this puzzle, we propose to consider the upward bias introduced by vertical specialization in the export series. Since the numerator of the variable export over GDP is gross value and the denominator is value-added, there are no reasons to think that the so-called openness ratio has to be bounded between 0 and 1. Thus, vertical specialization emerges as a potential explanation for the presence of unit roots, which is precisely the hypothesis that we test for the ten developed countries of the OECD in what follows.

As we said before, Hummels *et al*. (2001) provide scattered information about the percentage of imports embodied in the domestic exports of ten developed countries between 1970 and 1990. This analysis was updated by Chen *et al.* (2005) so that, in total, including the estimations of Minondo and Rubert (2002) for Spain, we have information for the countries and years specified in Table 5[30].

[30] There are VS trade estimations for other countries: Cardaso *et al*. (2007) estimate the measure for nine European countries, Breda *et al*. (2007) for Italy and six other European countries, Dean *et al*. (2007) for China and Cheng and Chang (2006) for Taiwan and South Korea and WTO (2008) for 28 countries. We do not use this information because it is only provided for one year or two at the most.

As seen in the previous section, when applying a time-series analysis, we find that the series of exports over GDP show a unit root for most of these ten countries. The key question is to what extent this non-stationarity is merely reflecting the advance in vertical specialization of recent decades. To explore this possibility, we start by constructing new series of openness after removing the multi-accounting bias. From the information available for the countries and years specified in Table 5 and the openness ratios constructed with the data provided by the International Financial Statistics (IMF), we have created a new measure *X*/GDP*, representative of the real value added exported (*X**) by a particular country over its *GDP*.

This variable *X*/GDP* for a country *k* is defined as follows:

$$\frac{X_k^*}{GDP_k} = \frac{X_k - VS_k}{GDP_k}$$

where X is the value taken from the IMF statistics and VS is the value of imports embodied in the domestic export value. Thus, this variable, which represents only the value embodied and exported by the country itself, is free from the foreign added valued incorporated by the multi-accounting associated with vertically specialized trade. We have then interpolated to create yearly series from 1968, when many authors establish the beginning of the vertical specialization phenomenon, to 2005. We have used cubic spline polynomials, which are the approximating functions of choice when a smooth function is to be approximated locally and are preferable to the method of truncated Taylor series. The general idea of any interpolation method is to compute the values of *f(x)* in the interval *[a,b]* knowing *f(a)* and *f(b)* [31].

[31] The truncated Taylor series provides a satisfactory approximation for the series at each point *x* if its path is sufficiently smooth and the interpolation point is sufficiently close to *a* or *b*. But if a function is to be approximated on a larger interval, the degree, of the approximating polynomial may have to be chosen unacceptably large. The alternative is to subdivide the interval *[a,b]* of approximation into sufficiently small intervals $[\zeta_j,...\zeta_{j+1}]$, with $a=\zeta_1<\ldots<\zeta_{j+1}=b$, so that, on each of them, a polynomial P_j of relatively low degree can provide a good approximation to the time series. This can even be done in such a way that the polynomial pieces blend smoothly, so that the resulting patched or composite function *s(x)* that equals

TABLE 5.— VS AS A SHARE OF MERCHANDISE EXPORTS: AVAILABLE DATA

Australia	Canada	Denmark	France	Germany	Japan	Netherlands	Spain	UK	US
1968	1971	1972	1972	1978	1970	1972	1970	1968	1972
1974	1976	1977	1977	1986	1975	1977	1990	1978	1977
1986	1981	1980	1980	1988	1980	1981	1994	1983	1982
1989	1986	1985	1985	1990	1985	1986		1990	1985
1995	1990	1990	1990	1995	1990	1995		1998	1990
		1997	1995		1995	1996			1997
					1996	1997			
					1997	1998			

Source: Chen el al. (2005) and Minondo and Rubet (2002) for Spain.

The new series are compared to the original ones in Figure 1, and they clearly show the advance of the new kind of trade after the late 1960s. Most importantly, the findings when analysing the statistical properties of the new series change radically. The results are in Table 6 and show how, when we take the vertically specialized trade into account, working with the variable *X*/GDP*, the unit root test *MZGLS*ατ identifies three countries (France, Japan and the UK) as having a stationary trend. Also, the Perron and Yabu (2008) test confirms, as before, that there is at least one structural break in most of the series (see Table 7).

Table 8 shows the results of the LS (2004) test. We find that all the series except the U.S. have a stationary trend when excluding the effect of the multi-accounting bias introduced by VS and simultaneously considering the possible presence of one break

Pj(x) for $x \in [\zeta_j,...\zeta\varphi+1]$, and all *j*, has several continuous derivatives. Any such smooth piecewise polynomial function is called a spline.

TABLE 6.— X*/GDP. UNIT ROOT TEST OF NG AND PERRON (2001)

Country	MZGLS
Australia	-0.571
Canada	-1.647
Denmark	-1.080
France	-2.715 [c]
Germany	0.099
Japan	-1.656 [c]
Netherlands	-0.964
Spain	-2.097
United Kingdom	-1.908 [c]
United States	-2.187

Critical values are provided in Ng and Perron (2001)

a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively

Spectral estimation method: AR spectral – GLS detrending

We use the Modified Akaike criterion to select the lag length the tests with a *kmax* equal to $\sqrt[3]{T}$

Source: own elaboration.

TABLE 7.— X*/GDP. PERRON AND YABU (2008): Exp-W_{FS}[1]

	X*/GDP		
Country	Model A	Model B	Model C
Australia	15.2639 [a]	81.2075 [a]	90.6548 [a]
Canada	5.5349 [a]	0.3496	5.1141 [a]
Denmark	11.1370 [a]	0.4699	29.7873 [a]
France	0.8435	0.0614	0.7941
Germany	4.8582 [a]	0.7757	16.1011 [a]
Japan	2.3201 [b]	0.2777	2.3776
Netherlands	12.7608 [a]	0.1362	12.9237 [a]
Spain	3.4188 [a]	0.2059	1.6977
United Kingdom	1.6599 [c]	0.1853	2.6651
United States	0.9623	0.0985	0.8594

[1] Critical values are provided in Perron and Yabu (2008)

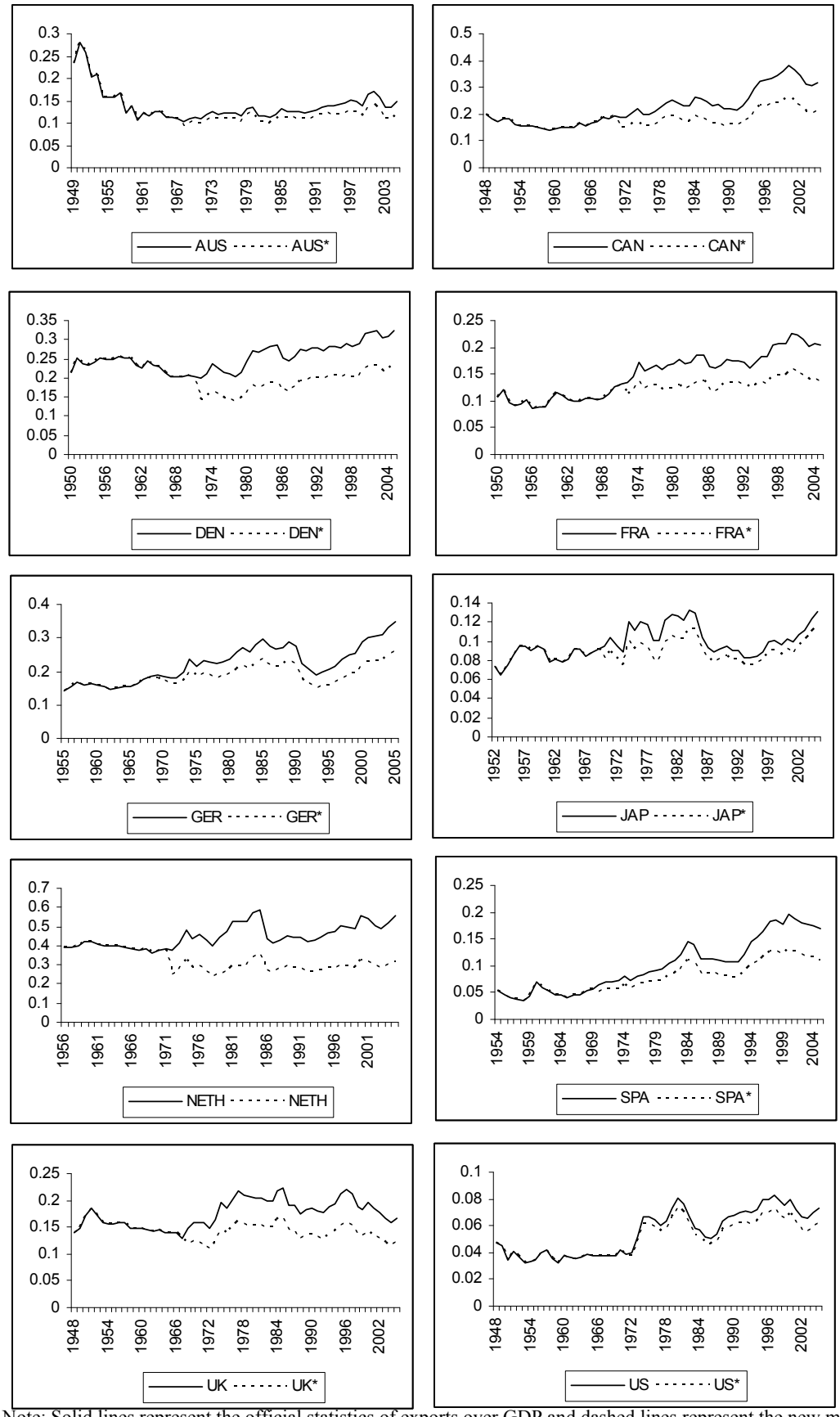
a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively

Models A, B and C [Perron 1989] represent changes in levels, trend and both levels and trend together, respectively

Source: own elaboration.

in the ratio of openness. Nine series become broken trend stationary in contrast with the three countries that we found (Australia, Germany and the U. K.) when we worked with the official series of exports. When we consider the possibility of two breaks, the results are very similar: eight stationary series out of the ten, as shown in Table 9. In this case, Canada does not become stationary.

FIGURE 1.--EXPORTS OVER GDP, 1948-2005



Note: Solid lines represent the official statistics of exports over GDP and dashed lines represent the new measure $\left(X^{*}/GDP\right)$: export, net of imported inputs, over GDP. Source: own elaboration.

To sum up, the last two tables clearly illustrate how vertical specialization affects the stochastic properties of the international trade series, in that stationary trends characterize exports over GDP series once we have removed the bias associated with vertical specialization and once the deterministic components of the Data Generating Processes are considered correctly.

TABLE 8.— X*/GDP. MINIMUM LM UNIT ROOT TEST (ONE BREAK)

Country	Model [1]	Break time	t-statistic	AIC [2]
Australia	C	1960	-5.2422 [b]	-8.820
Canada	C	1995	-4.3588 [a]	-9.431
Denmark	C	1972	-4.2594 [a]	-9.048
France	C	1998	-5.5912 [c]	-10.042
Germany	C	1990	-5.0459 [c]	-9.576
Japan	C	1990	-4.9661 [b]	-10.163
Netherlands	A	1971	-4.1205 [b]	-7.999
Spain	A	1962	-3.2038 [a]	-10.037
United Kingdom	A	1973	-3.8512 [b]	-9.815
United States	A	1973	-2.871	-11.044

a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively. Critical values in Lee and Strazicich (2004)

We apply the general-to-specific procedure, described in Ng and Perron (1995), to select the number of lags with a kmax equal to $\sqrt[3]{T}$

[1] Model A: break in levels. Model C: break in both levels and trend. [Perron 1989]

[2] Information criterion of Akaike

Source: own elaboration.

TABLE 9.— X*/GDP. MINIMUM LM UNIT ROOT TEST (TWO BREAKS)

Country	Model [1]	Break time	t-statistic	AIC [2]
Australia	C	1961, 1967	-7.274 [a]	-9.603
Canada	C	1964, 1992	-4.88	-9.507
Denmark	C	1959, 1975	-5.957 [b]	-9.527
France	C	1970, 1996	-6.984 [a]	-10.327
Germany	C	1989, 1998	-6.556 [a]	-9.679
Japan	C	1979, 1990	-5.884 [b]	-10.421
Netherlands	A	1971, 1975	-4.090 [b]	-8.008
Spain	A	1960, 1962	-3.721 [c]	-10.127
United Kingdom	A	1966, 1973	-3.948 [b]	-9.990
United States	A	1973, 1998	-2.990	-11.059

a, b and c denote a statistic significant at the 1%, 5% and 10% level respectively. Critical values in Lee and Strazicich (2003)

We apply the general-to-specific procedure, described in Ng and Perron (1995), to select the number of lags with a kmax equal to $\sqrt[3]{T}$

[1] Model A: break in levels. Model C: break in both levels and trend. [Perron 1989]

[2] Information criterion of Akaike

Source: own elaboration.

V. Conclusion

The goal of this paper has been to show how the progress of vertical specialization can explain the puzzle of finding unit roots in the series of openness of developed countries in the second half of the twentieth century. Our hypothesis is that the unit roots are reflecting the upward bias introduced by the vertical specialization into the numerator of the openness series, as a consequence of which, the export shares of GDP are not necessarily bounded between 0 and 1. To test this hypothesis, we have started by analysing a large sample of countries and found a clear pattern of stationarity for the openness series of LDC in contrast to the pattern of unit roots of DC. The next step was to test whether vertically specialised trade was responsible for this unit root pattern in DC. We used the scattered data of vertical specialization for ten OECD countries to construct new yearly export series of domestic added value exported. Corroborating our hypothesis, we have found that, when the statistical analysis is applied to the unbiased series of openness, the majority of countries (nine out of ten) became stationary, in contrast to the results obtained for the original openness series, where only three out of the ten exhibited a stationary trend.

This paper, consequently, both illustrates the influence of vertical specialization on the stochastic properties of the international trade series and rationalizes the econometric puzzle of typifying external openness (when vertical specialization is not taken into account) as series with a unit root.

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