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Does structure influence growth? A panel data econometric assessment of 'relatively less developed' countries, 1979-2003

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Abstract

Neo-Schumpeterian streams of research emphasize the close relationship between changes in economic structure in favour of high-skill and high-tech branches and rapid economic growth. They identify the emergence of a new technological paradigm, strongly based on the application of information and communication technologies (ICTs), in the 1970s, arguing that in such periods of transition and emergence of new techno-economic paradigms the relatively less developed countries have higher opportunities to catch-up. Although this debate is theoretically well documented, the empirics seem to lag behind the theory. In this paper, we contribute to this literature by adding illuminating evidence on the issue. More precisely, we relate the growth experiences of countries which had relatively similar economic structures in the late 1970s, with changes occurring in these countries' structures between 1979 and 2003. The results reveal a robust relationship between structure and (labour) productivity growth, and lend support to the view that *producing* (though not user) ICT-related industries are strategic branches of economic activity.

Keywords: Structural change, Economic growth, Technical change.

JEL-Codes: O10; O30.

1. Introduction

Structural change refers primarily to changes in the sectoral composition of the economy (Wang and Szirmai, 2008; Silva and Teixeira, 2008), and may be driven either by demand-side factors, such as changes in domestic demand and in the structure of exports, or by supply-side factors, such as the re-allocation of labour and capital to more efficient uses.

The last two decades witnessed a new revival of interest on structural change and on its relationship with economic growth, which seems to be primarily related with the spread of neo-Schumpeterian theses (Silva and Teixeira, 2008). According to the arguments expressed in this branch of the economic literature [see especially Perez (1985) and Freeman and Perez (1988)], the emergence of major technological breakthroughs has a profound impact in the restructuring of the techno-economic and in the socio-institutional spheres of the economy. With respect to the sectoral composition of the economy, the introduction of a new 'technological paradigm' (Dosi, 1982) originates significant changes, with the dynamic set of industries that is more closely related with its exploitation assuming progressively higher importance and stimulating growth, whereas sectors associated with older technologies see their influence diminish. Along with these important developments, some theoretical models within the more orthodox branch of economics came also into play suggesting that countries specializing in high-tech sectors would observe high rates of productivity growth relative to other countries (Lucas, 1993; Grossman and Helpman, 1991). Lucas (1988) even suggested that it could pay off for a country to change its specialization pattern from low to high tech sectors by adopting adequate policy measures.

The emphasis put by these theoretical approaches on the relationship between technology advanced industries and economic growth, together with the debate on the impact of ICT on aggregate productivity growth, gave rise to a number of empirical studies examining the impact of structural change on economic growth (e.g., Fagerberg, 2000; Timmer and Szirmai, 2000; Peneder, 2003; Wang and Szirmai, 2008). Some of these studies consider a relatively large group of countries, taking together countries with marked structural differences (e.g., Fagerberg, 2000; Amable, 2000; Peneder, 2003), whereas others focus on individual countries or regions' experiences (e.g., Nelson and Pack, 1999; Timmer and Szirmai, 2000; Engelbrecht and Xayavong, 2007; Wang and Szirmai, 2008). To our knowledge, however, no attempt has been made yet to assess the specific role of technology-led branches in relatively less developed countries' growth trajectories. Moreover, the analysis of the impact of structural change on economic growth with respect to these countries has been carried out in essentially descriptive terms (i.e., using shift-share and growth accounting techniques), without making an assessment of the causality chains between changes occurring at the industry and macro levels of the economy.

In the present paper, we investigate the relationship between structural change and economic growth, adopting an econometric approach and taking into account a set of 10 'relatively less developed' countries in the late 1970s (Portugal, Spain, South Korea, Greece, Taiwan, Ireland, Italy, Japan, Austria and Finland). This restricted range of countries results from two fundamental aspects. First, the purpose of this work is not so much to assess globally the impact of technology-led sectors on economic growth, an issue that has already been addressed in the literature (e.g., Fagerberg, 2000; Peneder, 2003), but to investigate their specific importance with respect to relatively less developed countries. The period under analysis (1979-2003) was characterised by the emergence of a new technological paradigm, strongly based on the application of information and communication technologies (Freeman and Soete, 1997), which replaced the previous paradigm based on low-cost oil and mass-production technologies. According to some views expressed within the new Schumpeterian approach (e.g., Perez, 1985), it is precisely in periods of transition and emergence of new techno-economic paradigms that the relatively less developed countries have higher opportunities to catch-up. In these circumstances, it seems pertinent to compare economies that faced similar growth problems in the late 1970s and which have experienced widely different growth trajectories since then, and relate those experiences with changes occurring at the industry level of the economy. Secondly, given the strong empirical rejection of the hypothesis of a common growth model for all countries in favour of the hypothesis of different convergence clubs (e.g., Durlauf and Jonhson, 1992; Färe *et al.*, 2006), it does indeed seem more reasonable to analyse separately a group of economies that shared similar structural characteristics at the beginning of the period under study.

The paper is structured as follows. Section 2 identifies the list of countries to be compared by applying hierarchical cluster analysis. Section 3 provides a descriptive characterisation of the growth and structural change processes of the selected countries during the period under study. It is shown that a striking increase in the countries' dissimilarities came into play during this period, and an association between changes in economic performance and changes in economic structure is hypothesised. In Section 4, this hypothesis is examined through the estimation of a panel data regression, considering fixed effects methods. The results reveal a robust relationship between structure and (labour) productivity growth and lend some support to the view that ICT-related industries are strategic branches of economic activity, but only when producing industries are considered. The final section presents a brief summary and concludes.

2. Determining countries' structural similarity: a cluster analysis

2.1. Some considerations on the data

In order to identify the group of relatively less developed countries which shared similar structural characteristics in the late 1970s, a comparison of 21 countries (20 OECD members plus Taiwan) is undertaken.[1] This comparison is based on the countries' per capita income and on the relative importance of the countries' industry groups defined according to two complementary taxonomies: a taxonomy from Peneder (2002) which takes into account the industries' skill requirements,[2] and a taxonomy based on technological characteristics from Tidd *et al.* (2001), which constitutes a refinement of Pavitt's original classification scheme (Pavitt, 1984). More precisely, we compare the relative shares of low, medium and high-skill industries, as well as the relative shares of supplier-dominated, scale-intensive, specialised supplier, information-intensive and science-based industries in total VAB and employment figures. Along with these variables, we also consider a measure of the aggregate stock of human capital, expressed by the average number of years of formal education of the working age population (25 to 64 years). The choice of this variable reflects the crucial role of education in determining the capacity to assimilate advanced technologies from more developed countries, and to foster rapid structural change and economic growth.[3]
With regard to per capita income, we use data from the *World Economic Outlook Database* (April 2008) of the International Monetary Fund. This database provides full information regarding per capita GDP based on purchasing-power-parity (PPP) in current international dollars for a vast number of countries for the 1980-2007 period.

Data on sectoral VAB and employment (in hours) are taken from the 60-Industry Database of the Groningen Growth and Development Centre, which is available on-line at http://www.ggdc.net. This database covers 26 countries for 56 industries classified according

[1] The complete list of the countries considered can be found in Table 1.
[2] This taxonomy was originally developed for manufacturing industries only (Peneder, 2002), but O'Mahony and Vecchi (2002) provided an extension covering service sectors.
[3] See Fagerberg (1994) and Abramovitz (1986, 1994) for a discussion on the 'technology-gap' literature and on the specific concept of 'social capability'.

to the International Standard Industrial Classification (ISIC) revision 3. Table 1 presents our classification of the 56 industries according to the selected taxonomies.[4]

Table 1: Classification of sectors according to Peneder (2002)/O'Mahony and Vecchi (2002) and Tidd, Bessant and Pavitt's (2001) taxonomies

ISIC rev.3	Industries	Peneder (2002)/ O'Mahony and Vecchi (2002)	Tidd, Bessant and Pavitt (2001)
01	Agriculture	Low-skill	Supplier-dominated
02	Forestry	Low-skill	Supplier-dominated
05	Fishing	Low-skill	Supplier-dominated
10-14	Mining and quarrying	Low-skill	Scale-intensive
15-16	Food, drink & tobacco	Low-skill	Scale-intensive
17	Textiles	Low-skill	Supplier-dominated
18	Clothing	Low-skill	Supplier-dominated
19	Leather and footwear	Low-skill	Supplier-dominated
20	Wood & products of wood and cork	Medium-skill	Supplier-dominated
21	Pulp, paper & paper products	Medium-skill	Supplier-dominated
22	Printing & publishing	Medium-skill	Supplier-dominated
23	Mineral oil refining, coke & nuclear fuel	Medium-skill	Scale-intensive
24	Chemicals	High-skill	Science-based
25	Rubber & plastics	Low-skill	Specialised supplier
26	Non-metallic mineral products	Low-skill	Scale-intensive
27	Basic metals	Low-skill	Scale-intensive
28	Fabricated metal products	Medium-skill	Scale-intensive
29	Mechanical engineering	High-skill	Specialised supplier
30	Office machinery	High-skill	Specialised supplier
313	Insulated wire	Medium-skill	Specialised supplier
31-313	Other electrical machinery and apparatus nec	Medium-skill	Science-based
321	Electronic valves and tubes	Medium-skill	Specialised supplier
322	Telecommunication equipment	Medium-skill	Specialised supplier
323	Radio and television receivers	Medium-skill	Science-based
331	Scientific instruments	Medium-skill	Specialised supplier
33-331	Other instruments	Medium-skill	Specialised supplier
34	Motor vehicles	Medium-skill	Scale-intensive
351	Building and repairing of ships and boats	High-skill	Scale-intensive
353	Aircraft and spacecraft	High-skill	Scale-intensive
352+359	Railroad equipment and transport equipment nec	Medium-skill	Scale-intensive
36-37	Furniture, miscellaneous manufacturing; recycling	Low-skill	Supplier-dominated
40-41	Electricity, gas and water supply	Medium-skill	Scale-intensive

[4] Branches 24 ("Chemicals") and 50 ("Sale, maintenance and repair of motor vehicles,…") are defined as high-skill and low-skill, respectively, although to be precise we should consider them as medium/high-skill and low/medium-skill. This simplified classification was introduced to reduce the number of industry groups to be compared, in order to facilitate the determination of broad structural characteristics across countries. With respect to the Tidd *et al.* classification scheme, and following van Ark and Bartelsman (2004), we decided to include a separate category – non-market services – for the activities included in the 75, 80 and 85 ISIC rev.3 codes (public administration, education and health services). Generally, non-profit activities obey a distinct logic in terms of the relationship between innovation and productivity growth (Lumpkin and Dess, 1996; McDonald, 2007), and therefore it seemed reasonable to include them in a separate category.

45	Construction	Low-skill	Supplier-dominated
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	Low-skill	Information-intensive
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	Medium-skill	Information-intensive
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	Low-skill	Information-intensive
55	Hotels & catering	Low-skill	Supplier-dominated
60	Inland transport	Low-skill	Information-intensive
61	Water transport	Medium-skill	Information-intensive
62	Air transport	High-skill	Information-intensive
63	Supporting and auxiliary transport activities; activities of travel agencies	Medium-skill	Supplier-dominated
64	Communications	High-skill	Information-intensive
65	Financial intermediation, except insurance and pension funding	High-skill	Information-intensive
66	Insurance and pension funding, except compulsory social security	Medium-skill	Information-intensive
67	Activities auxiliary to financial intermediation	Medium-skill	Information-intensive
70	Real estate activities	High-skill	Information-intensive
71	Renting of machinery and equipment	Low-skill	Information-intensive
72	Computer and related activities	High-skill	Specialised supplier
73	Research and development	High-skill	Specialised supplier
741-3	Legal, technical and advertising	High-skill	Specialised supplier
749	Other business activities, nec	High-skill	Information-intensive
75	Public administration and defence; compulsory social security	Medium-skill	Non-market services
80	Education	High-skill	Non-market services
85	Health and social work	Medium-skill	Non-market services
90-93	Other community, social and personal services	Medium-skill	Supplier-dominated
95	Private households with employed persons	Medium-skill	Supplier-dominated
99	Extra-territorial organizations and bodies	Medium-skill	Non-market services

With regard to our measure of human capital stock, most of the data were taken from Bassanini and Scarpetta (2001). The authors extend de la Fuente and Doménech's (2000) earlier computations, determining the average number of years of formal education of the working age population on an annual basis over the 1971-1998 period.[5] We consider additionally Barro and Lee's (2001) estimates for the same variable for Korea and Taiwan, because these countries were not taken into account in Bassanini and Scarpetta's work.[6]

Table 2 presents the list of variables considered for our sample of 21 countries.

[5] Up to the early 1980s Bassanini and Scarpetta (2001) interpolate the five-year estimates provided by de la Fuente and Doménech (2000), whereas from that date onwards they calculate average years of education based on data from the OECD *Education at a Glance* (various issues), and consider the cumulative years of schooling in each educational level described in the OECD (1998: 347).

[6] Barro and Lee (2001) show that the estimates of educational attainment based on OECD data are quite similar to their own measures, and therefore the inclusion of a different source of information does not seem to be problematic. The major differences arise with respect to Germany and the UK, because of a different classification of educational attainment between the OECD and the UNESCO sources.

Table 2: Industry shares in VAB and employment hours (%), average number of years of formal education of the working age population and per capita income (1979, various countries)

	Low-skill		**Medium-skill**		**High-skill**		**Sup.-Dominated**		**Scale-intensive**		**Spec. supplier**		**Science-based**		**Inf.-Intensive**		**Non-market serv.**		**Education**	**PPPpcGDP[1]**
	VAB	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**YEARS**	**C. int. $**
Australia	40,7	48,1	31,0	34,8	28,3	17,1	25,1	30,6	19,7	13,4	5,6	5,4	1,8	1,5	31,1	33,0	16,7	16,0	11,5	9.809,8
Austria	42,0	56,6	35,7	28,0	22,2	15,5	28,2	42,8	14,8	11,7	6,1	6,5	2,4	1,9	31,9	22,6	16,6	14,6	10,3	10.495,0
Belgium	32,8	40,7	36,3	37,8	30,9	21,6	18,4	24,2	17,1	13,9	11,0	6,5	4,2	3,6	29,4	29,5	19,9	22,3	9,2	9.758,3
Canada	39,1	46,1	33,3	35,1	27,6	18,9	22,8	31,5	18,7	11,1	5,5	6,9	1,9	1,7	32,6	30,2	18,5	18,6	12,0	11.119,8
Denmark	32,3	41,8	38,7	37,4	29,0	20,8	21,2	28,7	9,7	9,2	7,1	7,7	1,7	1,7	37,9	28,5	22,3	24,2	10,5	10.038,2
Finland	37,5	51,8	38,2	33,5	24,4	14,6	33,4	43,2	13,2	8,6	6,3	5,6	2,0	1,4	30,0	23,5	15,1	17,6	9,5	8.763,6
France	33,3	45,1	33,4	34,2	33,4	20,8	23,5	33,7	11,5	11,5	10,7	8,2	2,8	1,8	34,2	25,7	17,2	19,0	9,5	9.985,8
Germany	31,0	41,9	39,1	38,0	30,0	20,0	21,0	28,4	16,6	14,5	11,4	10,1	5,3	4,0	28,7	24,3	16,9	18,6	11,2	9.796,7
Greece	53,4	69,8	21,9	20,0	24,7	10,2	38,9	55,6	9,5	9,8	2,9	3,3	0,9	0,9	34,7	20,6	13,0	9,9	7,9	8.515,3
Ireland	49,7	55,1	24,3	28,2	26,0	16,7	35,8	42,7	13,8	13,0	11,3	5,1	3,1	1,9	24,3	21,2	11,8	16,0	8,4	6.612,4
Italy	42,2	52,0	31,0	31,4	26,7	16,6	29,9	40,4	13,4	11,8	9,3	6,9	3,7	2,7	31,0	22,3	12,7	16,0	7,3	8.999,2
Japan	41,7	57,8	32,1	27,4	26,2	14,8	29,1	45,7	13,4	8,5	6,5	7,0	3,9	2,4	37,7	29,1	9,4	7,3	10,1	8.901,2
Korea	57,2	71,7	26,3	20,7	16,4	7,5	41,7	59,7	12,5	7,8	4,8	4,2	4,3	2,3	27,1	19,6	9,5	6,3	6,8[1]	2.486,8
Netherlands	33,0	39,4	41,0	40,7	25,9	19,8	21,9	31,3	15,0	10,0	6,3	6,1	4,0	3,2	29,3	27,7	23,5	21,7	10,0	10.696,1
Norway	37,8	42,6	36,2	39,1	26,0	18,2	19,6	31,4	21,8	11,1	4,8	5,0	2,0	1,7	34,6	28,2	17,2	22,6	10,6	12.576,6
Portugal	49,3	64,2	30,4	26,0	20,2	9,8	33,4	54,4	11,7	9,6	6,1	2,4	2,2	1,6	33,8	19,9	12,8	12,1	6,9	5.130,1
Spain	46,6	60,9	29,7	26,0	23,7	13,2	32,1	46,3	14,8	11,0	5,3	3,9	2,9	2,0	31,9	23,7	13,0	13,1	6,3	7.287,5
Sweden	27,5	36,8	43,6	42,6	28,9	20,7	23,4	29,2	12,2	10,5	8,1	8,0	2,0	1,8	31,8	24,8	22,4	25,9	10,0	9.953,5
Taiwan	47,0	63,5	31,9	26,7	21,1	9,8	30,3	47,7	18,0	9,4	6,5	8,2	5,0	4,7	29,4	21,5	10,8	8,4	6,4[1]	3.355,7
UK	34,8	43,7	34,4	33,8	30,9	22,5	21,1	27,3	18,8	15,5	9,6	8,8	3,2	2,9	30,4	27,8	16,9	17,7	10,0	8.636,4
US	31,8	37,1	37,5	37,7	30,7	25,2	18,9	25,6	14,4	10,7	9,2	8,5	2,7	1,9	35,9	29,0	19,0	24,3	12,2	12.255,1
Average	**40,0**	**50,8**	**33,6**	**32,3**	**26,3**	**16,9**	**27,1**	**38,1**	**14,8**	**11,1**	**7,3**	**6,4**	**3,0**	**2,3**	**31,8**	**25,4**	**16,0**	**16,8**	**9,4**	**8.817,8**
Std. Dev.	**8,1**	**10,7**	**5,4**	**6,4**	**4,1**	**4,7**	**6,9**	**10,6**	**3,3**	**2,1**	**2,4**	**2,0**	**1,2**	**0,9**	**3,4**	**3,9**	**4,1**	**5,7**	**1,8**	**2.602,3**
Max.	**57,2**	**71,7**	**43,6**	**42,6**	**33,4**	**25,2**	**41,7**	**59,7**	**21,8**	**15,5**	**11,4**	**10,1**	**5,3**	**4,7**	**37,9**	**33,0**	**23,5**	**25,9**	**12,2**	**12.576,6**
Min.	**27,5**	**36,8**	**21,9**	**20,0**	**16,4**	**7,5**	**18,4**	**24,2**	**9,5**	**7,8**	**2,9**	**2,4**	**0,9**	**0,9**	**24,3**	**19,6**	**9,4**	**6,3**	**6,3**	**2.486,8**

Source: Composition of economic activity: GGDC – 60 Industry Database; Education: Bassanini and Scarpetta (2001) and Barro and Lee (2001); Per capita income: IMF - World Economic Outlook Database (April 2008).

Notes: 1) Year of reference 1980.

As we can observe from Table 2, countries with larger per capita incomes tend to have higher educational capital stocks and relatively higher shares of high-skill industries. Inversely, countries with relatively low levels of GDP per capita income and human capital have higher shares of low-skill and supplier-dominated industries (the industry group with fewer technological opportunities).The US and Germany, for example, belong to the first group of countries, whereas Portugal, Greece and Korea are good representatives of the second, less developed group of countries.

This impression is confirmed by the computation of Pearson bi-variate correlation coefficients, considering both data on VAB or employment variables (cf. Table 3). The high positive relationship between education and per capita income and, inversely, the strong negative relationship of each of these variables and the relative shares of low-skilled and less innovative industries is clearly apparent. All the correlation coefficients relating education (or per capita GDP) to either the shares of low-skill or supplier-dominated industries are negative and strongly significant.

Table 3: Correlation matrix

VAB shares						
	High-skill	**Science-based**	**Spec. supplier**	**Sup.-dominated**	**Education**	**GDPper capita**
High-skill	1,00	-0,07	0,64***	-0,77***	0,64***	0,71***
Science-based		1,00	0,46**	-0,06	-0,24	-0,37
Specialised supplier			1,00	-0,43**	0,19	0,16
Supplier-dominated				1,00	-0,72***	-0,75***
Education					1,00	0,82***
GDP per capita						1,00

Employment shares						
	High-skill	**Science-based**	**Spec. supplier**	**Sup.-dominated**	**Education**	**GDPper capita**
High-skill	1,00	0,06	0,67***	-0,95***	0,75***	0,7***9
Science-based		1,00	0,52**	-0,18	-0,17	-0,27
Specialised supplier			1,00	-0,67***	0,51**	0,36
Supplier-dominated				1,00	-0,76***	-0,76***
Education					1,00	0,82***
GDP per capita						1,00

Notes: N = 21;***, ** Correlation is significant at the 0.01 and 0.05 levels, respectively (two-tailed test).

2.2. Hierarchical clustering results

Cluster analysis involves a number of different procedures that allow for the division of a specific dataset into distinct groups, such that the degree of homogeneity is maximal if the observations belong to the same group and minimal otherwise. In the present study, because we have a relatively small dataset, we use the hierarchical clustering approach to classify the individual observations into clusters of maximum homogeneity.

Hierarchical clustering identifies successive clusters by using previously established clusters. It can be either agglomerative or divisive, although the former is the most commonly used.[7] In the present case, we have opted for the agglomerative approach, starting with each case as a separate cluster and successively merging the two closest clusters until a single, all-inclusive cluster remains.

The application of hierarchical agglomerative clustering requires the prior definition of a criterion to determine the distance or similarity between cases. We apply the cosine similarity criterion, although there is no clear-cut indication as to this measure's superiority in comparison to the others.[8] It also requires the definition of the rules for cluster formation. In the present case, we use the average linkage between groups method, also known as UPGMA (Unweighted Pair Group Method using Arithmetic averages). This method defines the distance between two clusters as the average distance between all pairs of cases in the two different clusters.[9] Agglomerative clustering is applied to the standardised scores of the variables, rather than to their real values, because they are measured on different scales (industry share variables in percentage points, human capital in years, and per capita income in PPP current international US dollars).

Figure 1 presents the resulting dendrogram. The first vertical lines represent the smallest rescaled distance, which in the present case corresponds to the merging of Portugal, Spain and Korea. Subsequent vertical lines represent merges at higher distances, until only one cluster, encompassing all cases, is obtained.

[7] See Everitt et al. (2001) and Aldenderfer and Blashfield (1985) for more information on hierarchical cluster analysis and on cluster analysis procedures in general.
[8] Acknowledging the subjective nature of this choice, we have also considered distance measures, as well as the alternative similarity measure (the correlation of vectors). The resulting cluster solution was always the same.
[9] The UPGMA method seems to be preferable relative to single and complete linkage rules, since it uses information regarding all pairs of distances, and not just the nearest or the furthest.

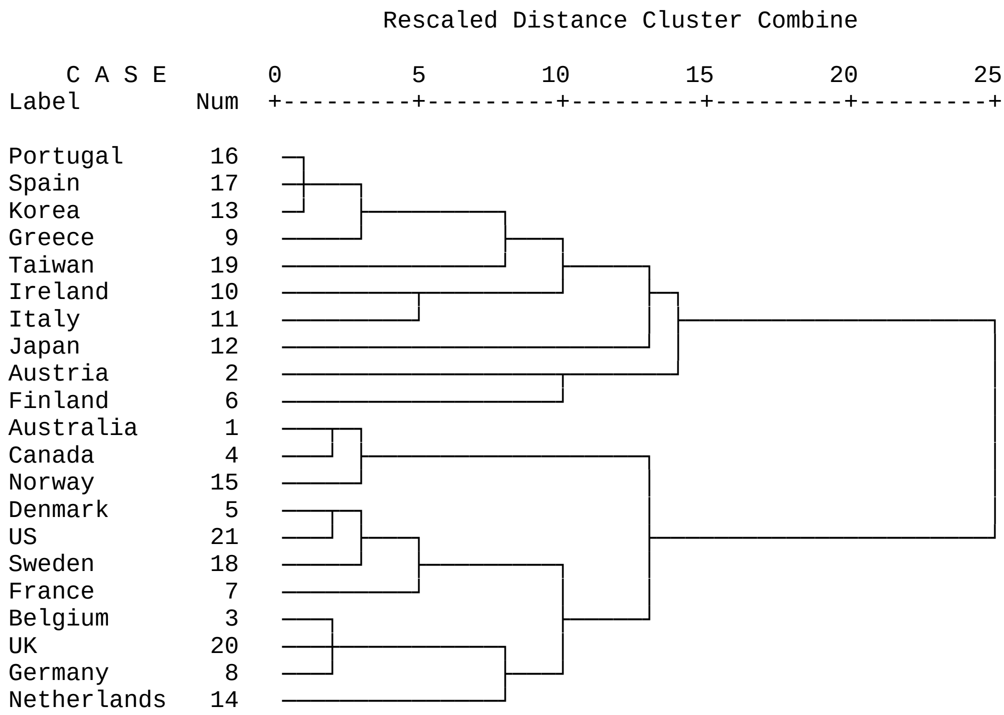

Figure 1: Dendrogram using average linkage between groups and the cosine similarity measure (1979)

Generally, a good cluster solution is defined as being the one which precedes a sudden gap in the similarity (or distance) coefficient. In this case, the larger distance between sequential vertical lines occurs approximately between 15 and 25, suggesting that the best clustering solution splits the list of countries into two clusters:

- A cluster formed by Portugal, Spain, South Korea, Greece, Taiwan, Ireland, Italy, Japan, Austria and Finland (*Cluster 1*);
- And a cluster including Australia, Canada, Norway, Denmark, US, Sweden, France, Belgium, UK, Germany and the Netherlands (*Cluster 2*).[10]

The clustering solution thus separates our sample into a cluster of highly developed countries (Cluster 2), characterised by high levels of education and per capita income, and relatively higher shares of innovative and high-skill industries, and a more heterogeneous cluster formed by relatively less developed countries (Cluster 1).

As can be seen from Table 4, there is indeed greater dispersion within Cluster 1, most particularly with regard to the per capita income variable. Countries such as Austria, Finland, Italy and Japan present considerably high values for this variable, close to the average value found for the countries included in Cluster 2, whereas Spain, Ireland, Portugal, and most

[10] This result does not change with the consideration of different linkage rules.

notably, Korea and Taiwan, are very far behind (cf. Table 5). As a matter of fact, Austria, Japan and Finland are classified in Cluster 1 mainly because of their composition of economic activity, which is characterised by a greater reliance on supplier-dominated industries and the weaker relevance of high-skill industries comparatively to countries included in Cluster 2. In contrast, countries such as Korea, Taiwan and Portugal present substantial differences in relation to the more developed countries in all the variables considered. These differences are particularly evident with respect to per capita income and human capital variables, and also in the (much higher) relevance of supplier-dominated industries.[11]

[11] It is worth mentioning, however, the contrasting evidence of Portugal, on the one hand, and of Taiwan and Korea, on the other, with respect to the relevance of science-based industries, which is considerably higher in these latter countries.

Table 4: Descriptive statistics - Clusters 1 and 2

	Low-skill (%)		Medium-skill (%)		High-skill (%)		Sup.-Dominated (%)		Scale-intensive (%)		Spec. supplier (%)		Science-based (%)		Inf.-Intensive (%)		Non-market serv (%).		Education	PPPpcGDP
	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	YEARS	C. int. dollar
Cluster 1																				
Average	46,7	60,3	30,2	26,8	23,2	12,9	33,3	47,8	13,5	10,1	6,5	5,3	3,0	2,2	31,2	22,4	12,5	12,1	8,0	7054,7
Std. Deviation	6,0	7,0	4,9	4,1	3,2	3,3	4,4	6,5	2,2	1,7	2,3	1,9	1,2	1,0	3,8	2,7	2,2	4,0	1,5	2637,0
Coef. of variation	12,8	11,5	16,4	15,5	13,9	25,5	13,2	13,6	16,4	16,6	35,4	35,1	40,3	46,3	12,2	12,2	18,0	32,8	19,0	37,4
Cluster 2																				
Average	34,0	42,1	36,8	37,4	29,2	20,5	21,5	29,3	16,0	12,0	8,1	7,4	2,9	2,4	32,3	28,1	19,1	21,0	10,6	10420,6
Std. Deviation	3,8	3,5	3,7	2,8	2,3	2,2	2,1	2,8	3,8	2,0	2,4	1,5	1,2	0,9	3,0	2,5	2,5	3,2	1,0	1162,6
Coef. of variation	11,3	8,4	10,0	7,4	7,7	10,6	9,6	9,6	23,6	17,1	29,7	21,0	41,1	37,9	9,3	8,9	13,2	15,1	9,4	11,2

Source: *Idem* Table 2

Table 5: Absolute distances of countries included in Cluster 1 relative to average values of cluster 2 (%)

	Low-skill (%)		Medium-skill (%)		High-skill (%)		Sup.-Dominated (%)		Scale-intensive (%)		Spec. supplier (%)		Science-based (%)		Inf.-Intensive (%)		Non-market serv (%).		Education	PPPpcGDP
	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	YEARS	C. int. dollar
Austria	8,0	14,4	-1,0	-9,4	-7,0	-5,0	6,7	13,5	-1,1	-0,2	-2,0	-0,9	-0,5	-0,4	-0,4	-5,5	-2,6	-6,4	-0,3	74,4
Finland	3,5	9,7	1,4	-3,8	-4,9	-5,9	11,9	14,0	-2,8	-3,3	-1,8	-1,8	-0,9	-0,9	-2,3	-4,5	-4,1	-3,4	-1,1	-1657,0
Greece	19,4	27,7	-14,9	-17,4	-4,5	-10,4	17,4	26,3	-6,5	-2,2	-5,2	-4,1	-1,9	-1,4	2,3	-7,5	-6,2	-11,1	-2,7	-1905,3
Ireland	15,7	13,0	-12,5	-9,2	-3,2	-3,8	14,2	13,4	-2,2	1,1	3,1	-2,3	0,2	-0,5	-8,0	-6,8	-7,4	-4,9	-2,2	-3808,2
Italy	8,2	9,9	-5,7	-6,0	-2,5	-3,9	8,4	11,1	-2,6	-0,1	1,1	-0,5	0,8	0,3	-1,3	-5,8	-6,4	-5,0	-3,3	-1421,3
Japan	7,7	15,7	-4,7	-10,0	-3,0	-5,7	7,5	16,4	-2,6	-3,5	-1,7	-0,3	1,0	0,1	5,4	1,0	-9,7	-13,7	-0,5	-1519,3
Korea	23,2	29,6	-10,5	-16,6	-12,8	-13,0	20,2	30,4	-3,4	-4,1	-3,3	-3,1	1,4	0,0	-5,2	-8,5	-9,6	-14,6	-3,8	-7933,8
Portugal	15,3	22,1	-6,3	-11,3	-9,0	-10,7	11,9	25,1	-4,3	-2,3	-2,0	-5,0	-0,7	-0,7	1,5	-8,2	-6,3	-8,9	-3,7	-5290,5
Spain	12,6	18,7	-7,0	-11,4	-5,6	-7,3	10,6	17,1	-1,2	-1,0	-2,8	-3,4	0,0	-0,4	-0,4	-4,4	-6,2	-7,9	-4,3	-3133,1
Taiwan	13,0	21,4	-4,9	-10,7	-8,1	-10,7	8,8	18,4	2,0	-2,5	-1,6	0,9	2,1	2,3	-3,0	-6,6	-8,4	-12,5	-4,2	-7064,9

Source: *Idem* Table 2. Notes: Absolute distance is calculated as the difference between the country's variable value and the corresponding average value of cluster 2.

3. Descriptive characterisation of the growth and structural change processes of ‘relatively less developed countries’ countries between 1979 and 2003

Countries in Cluster 1 – ‘relatively less developed countries’, which were rather similar in terms of economic structure in 1979, experienced very different processes of growth and structural change from that time onwards, which gave rise to a marked increase in their dissimilarities. Differences in per capita GDP, for example, were strongly amplified (see standard deviation figures in Table 6), given the profound differences in average growth rates of real GDP during this period. Korea, Ireland and Taiwan experienced very high GDP growth rates, whereas in the other countries, average GDP growth did not surpass 3% per annum (cf. Table 6).

Table 6: GDP at constant prices and GDP per capita based on purchasing-power-parity (annual % change; 1980-2003)

	GDP constant prices				GDP per capita (PPP)			
	1980-86	**1987-94**	**1995-03**	**1980-03**	**1980-86**	**1987-94**	**1995-03**	**1980-03**
Austria	1,6	2,6	2,2	**2,2**	6,3	5,0	3,8	**4,9**
Finland	2,7	0,8	3,8	**2,4**	7,0	3,4	5,4	**5,1**
Greece	0,2	1,4	3,6	**2,0**	4,3	3,5	5,0	**4,3**
Ireland	1,5	4,2	8,2	**5,0**	5,5	7,1	9,0	**7,4**
Italy	1,9	2,0	1,6	**1,8**	6,6	5,0	3,4	**4,8**
Japan	3,1	3,3	1,0	**2,3**	7,2	6,0	2,6	**5,0**
Korea	8,3	8,4	5,0	**7,0**	11,9	10,6	6,1	**9,1**
Portugal	1,8	4,3	2,7	**3,0**	6,3	7,4	4,0	**5,8**
Spain	1,7	3,0	3,8	**3,0**	5,9	5,8	4,9	**5,5**
Taiwan	7,5	8,1	4,6	**6,5**	10,9	10,2	5,7	**8,6**
Std deviation GDP per capita PPP								
1980	2637,0							
2003	5081,6							

Source: International Monetary Fund, World Economic Outlook Database, April 2008

Considerable differences arose, at the same time, with respect to labour productivity growth (cf. Table 7). Once again, higher growth rates occurred in Korea, Taiwan and Ireland, well above the ones observed in the other countries considered.

Table 7: Annual average labour productivity growth (%; 1979-2003)

	1979-1986	1987-1994	1995-2003	1979-2003
Austria	2,36	2,81	2,69	**2,63**
Finland	2,98	3,43	2,58	**2,98**
Greece	1,04	0,69	2,83	**1,59**
Ireland	3,61	4,29	6,78	**5,02**
Italy	1,84	2,20	0,78	**1,56**
Japan	3,41	4,05	2,63	**3,36**
Korea	5,55	6,24	5,20	**5,67**
Portugal	3,71	2,89	1,81	**2,72**
Spain	4,22	1,54	0,74	**2,01**
Taiwan	6,15	7,11	7,24	**6,86**

Source: GGDC 60-Industry Database
Notes: 1) Reference period: 1995-2002; 2) Reference period: 1979-2002.

Furthermore, rapid growth experiences were intimately connected with strong structural transformation. The computation of Nickell and Lilien indices of structural change (cf. Table 8) reveals that the fastest growth countries – Korea, Taiwan and Ireland – were simultaneously the countries with more rapid structural change during the period under study.[12] In contrast, slow-growing countries such as Greece or Italy experienced much more modest changes. This is in broad agreement with the views expressed by the authors from the new structuralist approach (e.g., Pieper, 2000; Rada and Taylor, 2006), according to which rapid growth requires profound changes in the composition of economic activity and external trade.

The countries with faster structural change were also the ones experiencing more profound changes in the relative importance of the industry groups defined earlier. Korea, Ireland and Taiwan were the countries in which the decrease in the relative share of low-skill industries was more intense. The lower importance of these industries was compensated by a substantial increase in high-skill industries, particularly in the cases of Ireland and Korea. Ireland, Korea and Taiwan also presented the largest decrease in supplier-dominated industries, which, as indicated earlier, are the industries facing lower technological opportunities. In contrast, relative shares of specialised supplier and science-based industries – Pavitt's top categories in technological and innovativeness potential – increased substantially (cf. Table 9).[13]

[12] See Lilien (1982) and Nickell (1985) for details on the computation of these indices.
[13] In Taiwan and Korea there was however a small decline in the relative importance of science based industries.

Table 8: Nickell and Lilien indices of structural change (1979-2003)[1]

	1979-1986	1987-1994	1995-2003	1979-2003
Nickell index				
Austria	0,185	0,188	0,214	**0,527**
Finland	0,213	0,227	0,318	**0,735**
Greece	0,166	0,187	0,386	**0,475**
Ireland	0,313	0,265	0,526	**0,885**
Italy	0,200	0,143	0,207	**0,505**
Japan	0,234	0,188	0,190[2]	**0,463**[3]
Korea	0,389	0,367	0,317[2]	**0,882**[3]
Portugal	0,223	0,310	0,245	**0,601**
Spain	0,242	0,182	0,187	**0,472**
Taiwan	0,277	0,359	0,283[2]	**0,807**[3]
Lilien index				
Austria	0,138	0,132	0,139	**0,274**
Finland	0,162	0,176	0,190	**0,404**
Greece	0,119	0,136	0,205	**0,315**
Ireland	0,243	0,214	0,364	**0,566**
Italy	0,169	0,111	0,136	**0,381**
Japan	0,163	0,128	0,164[2]	**0,352**[3]
Korea	0,281	0,298	0,224[2]	**0,635**[3]
Portugal	0,164	0,258	0,184	**0,477**
Spain	0,189	0,138	0,128	**0,346**
Taiwan	0,195	0,307	0,205[2]	**0,574**[3]

Source: GGDC 60-Industry Database

Notes: 1) Indices are calculated considering 56 sectors and sectoral proportions in value added. 2) Reference period: 1995-2002. 3) Reference period: 1979-2002.

Given the profound changes in the structure of their economies, it is no surprise that Korea, Ireland and Taiwan have been able to significantly modify their situation in comparison to the more developed countries included in Cluster 2. Indeed, as can be seen from Table 10, these countries have severely reduced the gap regarding the relative importance of low-skill and supplier-dominated industries, and converged, at the same time, in the more technological and skill-intensive categories. In the case of Ireland, in particular, there was not only a drastic reduction in the low-tech and low-skill industries distances, but also a substantial increase in the already positive gap with respect to specialised supplier and science-based industries.

Table 9: Industry shares in VAB in 2003 and variation between 1979 and 2003 (%)

	Low-skill		Medium-skill		High-skill		Sup.-Dominated		Scale-intensive		Spec. supplier		Science-based		Inf.-Intensive		Non-market serv.	
	VAB	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**	**VAB**	**Var. 79-03**
Austria	33,4	**-8,6**	35,6	**-0,1**	31,0	**8,7**	24,3	**-3,9**	11,1	**-3,7**	10,8	**4,7**	2,0	**-0,4**	35,9	**4,0**	16,0	**-0,6**
Finland	24,2	**-13,3**	41,9	**3,7**	33,9	**9,6**	22,2	**-11,2**	8,7	**-4,5**	13,2	**6,9**	2,2	**0,2**	35,2	**5,1**	18,5	**3,4**
Greece	42,4	**-10,9**	29,1	**7,2**	28,5	**3,8**	31,5	**-7,4**	8,4	**-1,1**	3,1	**0,2**	0,8	**-0,1**	38,8	**4,1**	17,3	**4,4**
Ireland	28,1	**-21,5**	28,9	**4,6**	42,9	**16,9**	21,3	**-14,5**	8,2	**-5,6**	16,8	**5,5**	14,6	**11,6**	24,5	**0,2**	14,6	**2,8**
Italy	31,9	**-10,4**	32,3	**1,2**	35,8	**9,1**	22,8	**-7,2**	10,2	**-3,2**	11,1	**1,8**	2,2	**-1,5**	38,1	**7,1**	15,6	**2,8**
Japan[1]	31,1	**-10,6**	34,2	**2,2**	34,7	**8,5**	23,5	**-5,6**	10,3	**-3,1**	8,0	**1,5**	2,7	**-1,2**	44,7	**7,0**	10,8	**1,4**
Korea[1]	33,6	**-23,6**	34,0	**7,7**	32,4	**16,0**	24,2	**-17,5**	17,1	**4,6**	9,5	**4,8**	3,7	**-0,6**	32,1	**4,9**	13,3	**3,8**
Portugal	34,2	**-15,1**	36,8	**6,3**	29,1	**8,8**	24,9	**-8,5**	9,9	**-1,7**	4,6	**-1,5**	1,4	**-0,7**	35,7	**1,9**	23,5	**10,7**
Spain	39,8	**-6,8**	30,3	**0,6**	29,9	**6,2**	30,4	**-1,7**	10,5	**-4,3**	7,1	**1,8**	2,2	**-0,7**	33,5	**1,6**	16,3	**3,4**
Taiwan[1]	26,9	**-20,1**	42,2	**10,3**	30,9	**9,8**	15,3	**-15,0**	12,3	**-5,7**	10,7	**4,2**	3,1	**-1,9**	43,9	**14,5**	14,7	**3,9**

Note: 1) Reference period: 1979-2002.

Table 10: Absolute differences in VAB industry group shares of countries included in cluster 1 relative to average values of cluster 2 (1979, 2003; %)

	Low-skill		Medium-skill		High-skill		Sup.-Dominated		Scale-intensive		Spec. supplier		Science-based		Inf.-Intensive		Non-market serv.	
	1979	**2003**	**1979**	**2003**	**1979**	**2003**	**1979**	**2003**	**1979**	**2003**	**1979**	**2003**	**1979**	**2003**	**1979**	**2003**	**1979**	**2003**
Austria	8,0	6,2	-1,0	-1,0	-7,0	-5,2	6,7	6,3	-1,1	-1,4	-2,0	0,4	-0,5	-0,4	-0,4	-1,3	-2,6	-3,7
Finland	3,5	-3,0	1,4	5,2	-4,9	-2,2	11,9	4,3	-2,8	-3,8	-1,8	2,9	-0,9	-0,2	-2,3	-2,0	-4,1	-1,2
Greece	19,4	15,2	-14,9	-7,6	-4,5	-7,7	17,4	13,6	-6,5	-4,1	-5,2	-7,2	-1,9	-1,6	2,3	1,6	-6,2	-2,3
Ireland	15,7	0,9	-12,5	-7,7	-3,2	6,8	14,2	3,3	-2,2	-4,3	3,1	6,5	0,2	12,2	-8,0	-12,6	-7,4	-5,1
Italy	8,2	4,7	-5,7	-4,4	-2,5	-0,3	8,4	4,8	-2,6	-2,3	1,1	0,8	0,8	-0,2	-1,3	1,0	-6,4	-4,1
Japan[1]	7,7	3,9	-4,7	-2,4	-3,0	-1,5	7,5	5,6	-2,6	-2,2	-1,7	-2,4	1,0	0,3	5,4	7,6	-9,7	-8,9
Korea[1]	23,2	6,4	-10,5	-2,7	-12,8	-3,7	20,2	6,3	-3,4	4,6	-3,3	-0,8	1,4	1,3	-5,2	-5,1	-9,6	-6,4
Portugal	15,3	7,0	-6,3	0,1	-9,0	-7,1	11,9	7,0	-4,3	-2,6	-2,0	-5,7	-0,7	-1,0	1,5	-1,5	-6,3	3,8
Spain	12,6	12,6	-7,0	-6,3	-5,6	-6,3	10,6	12,5	-1,2	-2,0	-2,8	-3,2	0,0	-0,2	-0,4	-3,6	-6,2	-3,4
Taiwan[1]	13,0	-0,3	-4,9	5,6	-8,1	-5,2	8,8	-2,6	2,0	-0,2	-1,6	0,4	2,1	0,7	-3,0	6,7	-8,4	-5,0

Note: 1) Reference period: 1979-2002.

Our findings seem to indicate furthermore that the influence of structural change on economic growth depends on its association with technological change. The case of Portugal is rather illustrative of this point. Despite showing relatively fast structural change between 1979 and 2003, Portugal did not significantly change the composition of its economy in terms of the industry groups considered. The country was able to reduce the relative importance of low-skill and supplier-dominated industries and to increase high-skill industry shares, but the rate at which this transformation took place was relatively low. Moreover, and quite significantly, the most important change observed during this period refers to non-market services, which increased their relative importance in about 11 percentage points. This has probably had an influence on the relatively poor performance of the Portuguese economy, when compared to other countries in the sample.

Considerable changes in education also came into play during this period.[14] All the countries increased the average number of years of formal education of the working age population, expanding human capital stocks (cf. Table 11). However, the rates at which this increase took place differed significantly across countries. Korea shows once more an impressive performance, along with Spain, Italy and Taiwan. Portugal, on the other hand, presents the weakest increase in the average number of years of formal education, and is the only country which widens the gap in comparison to the countries in cluster 2.

Table 11: Average number of years of formal education of the working age population (25-64 years) (1979-2003)

	Years		% change	Education gap[1]		
	1979	**2003**	**1979-2003**	**1979**	**2003**	**Var. (years)**
Austria	10,3	12,2	**18,8**	-0,3	-0,1	0,2
Finland	9,5	12,5	**31,3**	-1,1	0,1	1,2
Greece	7,9	10,4	**32,0**	-2,7	-1,9	0,8
Ireland	8,4	10,9	**29,7**	-2,2	-1,5	0,7
Italy	7,3	10,4	**42,7**	-3,3	-1,9	1,4
Japan	10,1	12,7	**25,8**	-0,5	0,3	0,8
Korea	6,8	10,8	**59,3**	-3,8	-1,5	2,3
Portugal	6,9	8,0	16,6	-3,7	-4,3	-0,6
Spain	6,3	9,7	**54,4**	-4,3	-2,6	1,7
Taiwan	6,4	8,8	**38,9**	-4,2	-3,5	0,7

Notes: 1) The education gap is defined as the difference between the country's value and the average of countries included in cluster 2.

[14] In order to get a full series of education data we extended Bassanini and Scarpetta's (2001) estimates up to 2003 using the author's methodology. We also applied this procedure to Korean and Taiwanese data, considering Barro and Lee's (2001) estimates. The complete data set and some details on the calculus procedure can be found in the annex.

The significant changes taking place during the period under study in each of the individual dimensions considered led to a substantial modification in the comparative situation of countries. This becomes more evident when cluster analysis is performed once more, this time considering 2003 figures.[15] In this case, the splitting of countries into two clusters is no longer clear-cut (cf. Figure 2). As a matter of fact, the clustering solution is somewhat unsatisfactory, since it does not provide a strong classification. A quite different outcome is now also admissible, characterised by four clusters with the following composition:

1) Greece, Spain, Portugal, Austria, Japan, Korea, Italy and Taiwan;
2) Australia, Canada, Norway;
3) Denmark, Netherlands, US, France, UK, Finland, Sweden, Belgium and Germany;
4) Ireland.

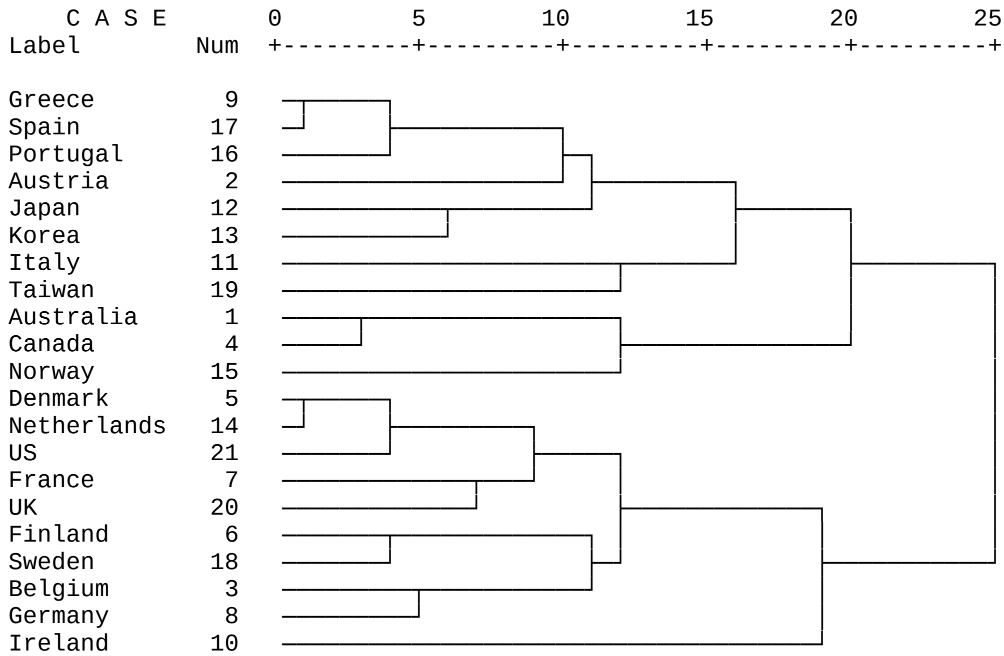

Figure 2: Dendrogram using average linkage between groups and the cosine similarity measure (2003)

Overall there is an increase in the countries' dissimilarities and some countries experience considerable changes, moving to very different clusters in comparison to the initial ones. This is the case of Finland, for example, and Ireland, which now stands alone in cluster 4.[16] Korea

[15] Data used to perform cluster analysis for 2003 can be found in the annex.
[16] As already noted, the initial inclusion of Finland in the cluster of relatively less developed countries was due to differences in the composition of economic activity, and particularly its stronger reliance on low-skill and supplier-dominated industries, and correlative deficit in high-skill and high technological opportunities industries. An analysis of the overall evolution of the country during this period, and particularly, of Tables 9, 10

also experiences a profound change, and is now quite distant from Portugal and Spain (very similar countries in 1979), and converging to Japan, which was initially at a considerably distance.

4. Regression analysis

The descriptive analysis developed so far suggests that an explanation for the widely different growth patterns observed between 1979 and 2003 for countries included in the relatively less developed cluster may reside in their differing ability to promote changes in the economic structure towards more skilled and technology-intensive activities. In the present section we go a step further in the examination of this hypothesis by regressing actual productivity growth in the VAB shares of some of the categories in the considered taxonomies (i.e., specialised suppliers, science-based, supplier-dominated and high-skill industries), and their changes over time. More precisely, we estimate the following fixed effects panel regression:

$$\begin{aligned}\Delta y_{it} = \alpha + \delta_j \Delta x_{i,t-1} + \chi_j x_{i,t-1} + \gamma EDUC_{i,t-1} + \beta \Delta EDUC_{i,t-1} + \varphi INV_{i,t-1} + \psi \Delta INV_{i,t-1} \\ + \omega EMP_{it} + \eta_t + \mu_i + \varepsilon_{it} \qquad (1)\end{aligned}$$

i = country index ($i = 1,\ldots, N$)
j = industry group(s) considered
t = time
ε_{it}= error term

In this expression, y_{it} is the logarithm of value added over employment (in hours) for country i in period t, N is the number of countries and x_i represents the VAB shares of the selected groups of industries in country i. The symbol Δ denotes first differences, for example, Δy_{it} is the change in the logarithm of value added per hour over a one-year period, or y_{it} - $y_{i,t-1}$.[17] Industry group shares (x_i) and their annual changes (Δx_i) are expressed in lagged values so that causality runs from industrial structure to productivity growth, and not the other way around. δ and χ are expected to be positive when industry shares refer to high-skill, specialised supplier and science-based industries, given their high productivity growth rates and the indirect positive effects they generate to other industries, through producer and user-related spillovers. More precisely, products and innovations originating in skills and

and 11, reveals, however, that Finland underwent profound structural transformation between 1979 and 2003, coming quite close to the structure of the countries initially included in cluster 2, while maintaining relative closeness in relation to the other dimensions considered (education and per capita income).

[17] Although other time intervals could be considered, such as 5-year or 10-year intervals, only the use of annual data can take into account all the available information.

technology-intensive sectors are likely to be conducive to productivity gains in other industries which use these products or find new applications for the innovations developed, and therefore increase productivity. Inversely, a negative sign is expected when supplier-dominated industry shares are considered.

A number of control variables are also included. The first of such variables is education (*EDUC*), expressed by the average years of education of the working age population, and its growth rate ($\Delta EDUC$). Once again these variables are expressed in lagged values in order to mitigate possible endogeneity problems. An extensive and ever-growing literature (e.g., Temple 1999, 2000; Lucas, 1998; Nelson and Phelps, 1966) attests the virtuous effects of the rise in human capital stock on growth, and therefore we expect both γ and β to be positive. The influence of physical capital accumulation is also taken into account through the inclusion of both the lagged values of the share of investment in GDP ($INV_{i,t-1}$) and its growth rate. The renewal rate of capital stock may influence positively productivity growth in various ways, namely through the embodiment of technology and innovation,[18] and consequently coefficients φ and ψ are expected to be positive. Finally, we control for business cycle effects including time dummies (η_t), and using the employment rate (*EMP*) to account for country-specific economic fluctuations.[19] Given the procyclical nature of labour productivity, we expect ω to be positive.

The estimations are carried out considering the sample of countries included in Cluster 1 over the 1980-2003 period.[20] The data source of industry VAB shares is the 60-Industry GGDC Database. Data on education were taken from Bassanini and Scarpetta (2001) and Barro and Lee (2001), and extended up to 2003 using OECD *Education at a Glance* data, as indicated in the previous section. Data on GDP and gross fixed capital formation are from the *OECD Factbook 2008: Economic, Environmental and Social Statistics*, with the exception of Taiwan, whose data was taken from the Taiwanese government official statistics.[21] Finally, employment rates are taken from the *World Economic Outlook Database (April 2008)*, developed by the International Monetary Fund.

Table 12 presents the estimation results.

[18] See in this respect Kaldor (1957) and, more recently, DeLong and Summers (1991).
[19] Both variables have been used previously in the literature to account for the influence of business cycle effects. See, for example, Peneder (2003).
[20] One observation was lost (1979), because data on employment and investment variables was only available from 1980 onwards. Data regarding Taiwan, Korea and Japan refer to the 1980-2002 period.
[21] Available on-line at http://eng.dgbas.gov.tw.

Table 12: The effect of structural change on productivity growth

Variable	Parameter	(i)		(ii)		(iii)		(iv)	
Δx_high skill *(t-1)*	δ			0.139**	(2.188)			0.146*	(1.868)
Δx_science-based *(t-1)*	δ					0.001	(0.035)	-0.001	(-0.063)
Δx_spec. supplier *(t-1)*	δ					0.006	(0.186)	0.005	(0.171)
Δx_sup.-dominated *(t-1)*	δ					-0.0983	(-1.399)	-0.0172	(-0.208)
x_high-skill *(t-1)*	χ			0.125	(1.008)			-0.253	(-1.315)
x_science-based *(t-1)*	χ					0.351**	(2.545)	0.316**	(2.182)
x_specialised supplier *(t-1)*	χ					-0.122	(-0.753)	-0.058	(-0.356)
x_supplier-dominated *(t-1)*	χ					-0.148	(-1.279)	-0.322**	(-2.021)
$EDUC_{t-1}$	γ	-0.504	(-0.961)	-0.544	(-1.044)	-0.421	(-0.745)	-0.545	(-0.962)
$\Delta EDUC_{t-1}$	β	0.037	(0.163)	0.105	(0.437)	0.128	(0.531)	0.109	(0.450)
INV_{t-1}	φ	-0.042	(-0.564)	-0.028	(-0.373)	0.044	(0.544)	0.076	(0.905)
ΔINV_{t-1}	ψ	0.072***	(2.674)	0.077***	(2.903)	0.066**	(2.387)	0.054*	(1.887)
EMP	ω	0.001	(0.013)	-0.023	(0.7410)	-0.103	(-1.342)	-0.083	(-1.090)
R^2		**0,52**		**0,55**		**0,56**		**0,57**	
Nr. of observations		**227**		**227**		**227**		**227**	
Nr. of countries		**10**		**10**		**10**		**10**	

Notes: The dependent variable is the change in the logarithm of value added per hour worked; Δvar, variable in first differences; $\Delta var_{(t-1)}$ lagged differences. Time dummies (η_t) included. *T*-values between brackets. ***, **, * Significance at the 1, 5 and 10% significance level.

The results confirm our hypothesis according to which structure influences (labour) productivity growth. In global terms, the coefficients for the structural variables turn up with the expected signs and are significant, even when all the variables are included in the regression (Specification iv). The lagged change in high-skill industries share affects positively labour productivity growth, which also applies with respect to the lagged share of science-based industries. Regarding the latter, an increase in one percentage point results in additional productivity growth of about 0.3 percentage points (Specifications iii and iv), which is a rather strong impact. In contrast, and as expected, an increase in the VAB share of supplier-dominated industries results in a decline in labour productivity growth.[22] Only variables for specialised supplier industries are deemed to be non-significant.

Regarding the conditioning variables, only the coefficient for the lagged variation of the share of investment in GDP turns up significant. This variable shows strong robustness, presenting coefficients ranging between 0.05 and 0.08, approximately, which are significant in all the specifications estimated. The employment rate, used to control for the influence of country-specific business cycles, is always non-significant.

In terms of education, the level variable (EDUC) presents a negative sign, although it is never statistically significant. When variation in educational achievements is considered, however, the coefficient for the education variable turns up with the right sign, although it is not statistically significant. The negative sign (although insignificant) of the EDUC variable may be due to the fact that countries with relatively poor educational achievements (in levels) in our sample were simultaneously the ones experiencing higher productivity growth performances. Furthermore, the overall counterintuitive result of education having an insignificant impact on productivity growth may result from the fact that our education indicator takes solely into account advances in formal education, excluding other forms of learning, and neglecting, at the same time, differences in the quality of educational attainments. [23]

The positive effect of both high-skill and science-based industries on productivity growth, controlling for the influence of other variables that might also influence growth, and particularly its strong impact, considerably above investment in physical capital, gives empirical support to our hypothesis according to which substantial benefits have accrued to

[22] The coefficient regarding this variable turns up insignificant, however, in specification iii.

[23] The insignificant contribution of human capital to productivity growth appears many times in the literature, especially when panel data is used. See Temple (1999) for a detailed analysis of the possible causes behind this counterintuitive result.

countries that successfully changed their structure towards more technologically advanced industries. Moreover, the fact that two of the three industries included within the science-based group are ICT-related industries ("Radio and television receivers", and "Other electronic machinery and apparatus") seems to be in global agreement with the techno-economic paradigm conceptualisations developed within neo-Schumpeterian strands of research. Those theories strongly emphasise the links between the *local* development of industries associated with the dominant technological paradigm, which in this period is represented by the 'electronic revolution', and the overall growth prospects of the economy. Technical change is conceived as a cumulative and path-dependent 'learning' process that is strongly embedded in organisational and institutional structures. Consequently, in order to fully exploit the benefits arising from new techno-economic paradigms, changes must occur in the industrial composition of the economy, along with wider changes in institutional and socio-economic levels.

We now investigate further this hypothesis by estimating Equation (1) once more, this time considering the ICT taxonomy used by van Ark and Bartelsman (van Ark and Bartelsman, 2004), which ranks industries according to their production or use of ICT. Table 13 presents the results.

As in the previous regressions, an increase in the investment growth rate exerts a positive influence on productivity growth. More precisely, an increase in the growth rate of investment by one percentage point amounts to an increase in labour productivity growth of about 0.07 percentage points. The other control variables are once again statistically insignificant.

The contribution of the lagged share of ICT-producing manufacturing industries is significantly positive when taken in isolation, and has a strong impact on the growth of productivity. A difference of one percentage point in the ICT-producing manufacturing lagged share gives a difference of over 0.3 percentage points in the annual productivity growth rate. However, when ICT-producing services are included, the χ coefficient ceases to be significant at the conventional significance levels, although keeping the correct sign and the relative magnitude. This might be due to a multicollinearity problem.

The coefficients for the lagged change in the share of ICT-producing services industries are always positive and statistically significant. In contrast, there is no significant impact of ICT-using industries on annual productivity growth.

Table 13: The effect of structure and structural change on productivity growth _ICTs

Variable	Parameter	(v)		(vi)		(vii)		(viii)		(ix)		(x)		(viii)	
Δx_ICTPM *(t-1)*	δ	-0.008	(-0.616)			-0.004	(-0.295)							-0.006	(-0.396)
Δx_ICTPS *(t-1)*	δ			0.056**	(2.185)	0.050*	(1.931)							0.049*	(1.807)
Δx_ICTUM *(t-1)*	δ							-0.001	(-0.020)			-0.007	(-0.192)	0.011	(0.288)
Δx_ICTUS *(t-1)*	δ									-0.037	(-0.707)	-0.040	(-0.722)	-0.021	(-0.375)
x_ICTPM *(t-1)*	χ	0.361*	(1.675)			0.311	(1.392)							0.346	(1.450)
x_ICTPS *(t-1)*	χ			-0.218	(-0.548)	-0.324	(-0.802)							-0.328	(-0.742)
x_ICTUM *(t-1)*	χ							-0.106	(-0.416)			0.042	(0.122)	-0.139	(-0.379)
x_ICTUS *(t-1)*	χ									0.086	(0.724)	0.098	(0.590)	-0.022	(-0.125)
$EDUC_{t-1}$	γ	-0.653	(-1.228)	-0.381	(-0.725)	-0.538	(-1.003)	-0.526	(-0.987)	-0.566	(-1.058)	-0.556	(-1.028)	-0.575	(-1.040)
$\Delta EDUC_{t-1}$	β	0.067	(0.288)	0.072	0.303	0.114	(0.473)	0.014	(0.057)	0.052	(0.223)	0.064	(0.255)	0.088	(0.342)
INV_{t-1}	φ	-0.011	(-0.139)	-0.037	(-0.500)	-0.008	(-0.097)	-0.053	(-0.671)	-0.050	(-0.644)	-0.048	(-0.597)	-0.010	(-0.126)
ΔINV_{t-1}	ψ	0.069**	(2.554)	0.066**	(2.378)	0.061**	(2.192)	0.074***	2.694	0.076***	(2.776)	0.076***	(2.718)	0.064**	(2.186)
EMP	ω	-0.023	(-0.337)	0.002	(0.036)	-0.012	(-0.171)	0.019	(0.236)	0.013	(0.179)	0.007	(0.078)	0.005	(0.054)
R^2		**0,54**		**0,54**		**0,55**		**0,53**		**0,53**		**0,53**		**0,55**	
Nr. of observations		**227**		**227**		**227**				**227**		**227**		**227**	
Nr. of countries		**10**				**10**		**10**		**10**		**10**		**10**	

Notes: The dependent variable is the change in the logarithm of value added per hour worked; Δvar, variable in first differences; $\Delta var_{(t-1)}$ lagged differences.
ICTPM- ICT producing manufacturing; ICTPS – ICT producing services; ICTUM – ICT using manufacturing; ICTUS – ICT using services. Time dummies (η_t) included.
T-values between brackets. ***, **, * Significance at the 1, 5 and 10% significance level.

Taken as a whole, these results lend some support to the view that ICT-related industries are strategic branches of economic activity, but only when *producing industries* are considered. This accentuates the fact that most spillovers from advanced industries, and particularly ICT-producing industries are *local* and national in character, and therefore that 'buying' is not the same as 'producing'. Hence, our results may be seen as reinforcing previous empirical evidence indicating that the gains from the diffusion of new technologies are especially relevant in economies which produce these technologies (e.g., Jaffe *et al.*, 1993; Maurseth and Verspagen, 1999; Jaffe and Trajtenberg, 2002).

5. Conclusion

This paper investigates the relationship between structural and technological change and economic growth, taking into account a number of relatively less developed countries in the late 1970s. According to neo-Schumpeterian theses, there are reasons to expect technological leading industries, and particularly those more closely related to new technological paradigms, to have a major influence on growth. Moreover, according to some of the views expressed (e.g., Perez, 1985), it is precisely in periods of transition and emergence of new techno-economic paradigms that the relatively less developed countries have higher opportunities to catch-up.

The preliminary descriptive analysis undertaken revealed that rapid growth experiences were intimately connected with strong structural transformation, measured by the computation of Nickell and Lilien indices. Furthermore, the countries with faster structural change were also the ones experiencing more profound increases in the relative importance of skills and innovation-intensive industries, and the largest decreases in low-skill and supplier-dominated industries. These results suggested that an explanation for the widely different growth patterns observed between 1979 and 2003 for the selected countries might reside in their differing ability to promote changes in the economic structure towards more skilled and innovation-intensive activities.

This hypothesis has been put under examination in the last part of the paper, through the estimation of a panel data regression, considering fixed effects methods. According to our findings, high-skill and science-based industries have a positive and significant impact on productivity growth, considerably above the influence of investment in physical capital. The results thus provide empirical support to the hypothesis according to which substantial benefits have accrued to countries that successfully changed their structure towards more technologically advanced industries.

Moreover, when ICT-related industries – the industries underlying the technological revolution of the period under analysis – are explicitly included in the estimation, the coefficients on ICT-producing industries are positive and statistically significant. This result lends some support to the view that ICT-related industries are strategic branches of economic activity, but only when *producing industries* are considered. This accentuates the fact that most spillovers from advanced industries, and particularly ICT producing industries are *local* and national in character, and therefore that 'buying' is not the same as 'producing'. Contrarily to the conclusions presented in other studies (e.g., Barros, 2002), we therefore argue that the implementation of industrial policies aimed at changing the pattern of specialisation towards the promotion of leading technology sectors may pay-off. [24]

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[24] Not necessarily ICT industries, since leading technologies change over time.

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Annex

Table A.1: Average years of education of the working age population, 1979-2003

	1979	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Austria	10,3	10,4	10,5	10,6	10,7	10,8	10,9	10,9	11,0	11,1	11,2	11,3	11,3	11,4	11,4	11,4	11,5	11,6	11,7	11,8	11,9	12,1	12,1	12,2	12,2
Finland	9,5	9,6	9,7	9,7	9,8	9,9	10,0	10,1	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8	10,9	11,0	11,1	11,2	11,5	11,8	12,1	12,4	12,5
Greece	7,9	7,9	8,0	8,1	8,2	8,2	8,3	8,4	8,5	8,6	8,7	8,8	9,0	9,1	9,2	9,3	9,5	9,6	9,7	9,9	10,2	10,2	10,3	10,4	10,4
Ireland	8,4	8,5	8,6	8,7	8,8	8,9	9,0	9,0	9,1	9,2	9,3	9,4	9,5	9,6	9,7	9,8	10,0	10,1	10,2	10,3	10,5	10,6	10,8	10,9	10,9
Italy	7,3	7,3	7,4	7,5	7,6	7,7	7,8	7,9	8,0	8,1	8,2	8,4	8,5	8,6	8,8	9,0	9,2	9,4	9,6	9,8	10,0	10,1	10,2	10,4	10,4
Japan	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8	10,9	11,0	11,1	11,2	11,4	11,5	11,6	11,7	11,9	12,0	12,1	12,3	12,3	12,4	12,5	12,7	12,7
Korea	6,8	6,8	7,0	7,3	7,5	7,8	8,0	8,3	8,5	8,7	9,0	9,3	9,4	9,6	9,7	9,9	10,1	10,2	10,2	10,3	10,4	10,5	10,5	10,6	10,8
Portugal	6,9	6,9	6,9	7,0	7,0	7,0	7,1	7,1	7,1	7,2	7,2	7,2	7,3	7,3	7,4	7,5	7,5	7,6	7,7	7,7	7,8	7,8	7,8	7,8	8,0
Spain	6,3	6,3	6,4	6,5	6,6	6,7	6,8	6,9	7,0	7,1	7,2	7,3	7,5	7,6	7,8	7,9	8,1	8,3	8,5	8,7	9,1	9,3	9,5	9,6	9,7
Taiwan	6,4	6,4	6,5	6,6	6,7	6,8	6,9	7,0	7,1	7,2	7,3	7,4	7,6	7,7	7,8	7,9	8,0	8,1	8,2	8,3	8,4	8,5	8,6	8,7	8,8

Notes: Data for the 1979-1998 period regarding all countries, except Korea and Taiwan, is from Bassanini and Scarpetta (2001). We extend Bassanini and Scarpetta's estimates up to 2003, considering data on educational attainment from OECD *Education at a Glance* (various issues), and using the cumulative years of schooling by educational level considered by the authors.

Data on Korea and Taiwan between 1980 and 2000 is based on Barro and Lee (2001). We interpolate the five-year observations provided by the authors to obtain annual figures for both countries. Education estimates for Korea between 2001 and 2003 were obtained considering data on educational attainment from OECD *Education at a Glance*, and assuming the cumulative years of schooling used by Barro and Lee (2001). Finally, estimates regarding Taiwan for 2001, 2002 and 2003 were obtained assuming that the average years of education of the working age population during this period has grown at an annual rate similar to the one experienced in the previous quinquennium.

Table A.2: Industry shares in VAB and employment hours (%), average number of years of formal education and per capita income (1979, various countries)

	Low-skill		Medium-skill		High-skill		Sup. Dominated		Scale intensive		Spec. supplier		Science based		Inf. Intensive		Non-market serv.		Education	PPPpcGDP
	VAB	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**VAB**	**HOURS**	**YEARS**	**C. int. dollar**
Australia	33,0	42,4	30,8	32,6	36,2	25,0	20,9	29,4	13,7	7,9	8,0	8,5	1,1	0,8	40,8	33,2	15,5	20,1	12,6	30.111,5
Austria	33,4	44,7	35,6	33,7	31,0	21,7	24,3	34,5	11,1	8,1	10,8	9,6	2,0	1,5	35,9	26,7	16,0	19,6	12,2	31.366,3
Belgium	25,1	29,4	36,2	40,2	38,7	30,3	14,9	19,5	10,4	8,3	15,3	9,1	4,1	2,7	34,3	32,5	21,0	27,9	11,3	29.059,8
Canada	31,9	40,1	35,1	35,6	32,9	24,3	18,7	28,0	16,1	8,1	6,8	10,1	1,6	0,9	39,4	34,0	17,4	18,9	13,5	31.808,5
Denmark	25,1	31,1	40,4	42,8	34,5	26,1	18,2	23,0	10,0	6,5	8,8	9,5	2,8	2,1	37,1	29,7	23,1	29,2	11,9	30.302,6
Finland	24,2	36,5	41,9	41,3	33,9	22,2	22,2	29,8	8,7	6,6	13,2	10,5	2,2	1,5	35,2	25,5	18,5	26,1	12,5	27.492,4
France	24,7	33,6	35,8	37,8	39,5	28,5	18,9	25,2	8,3	8,0	10,8	10,1	2,0	1,3	38,5	30,6	21,5	24,9	11,4	28.119,5
Germany	22,3	33,2	38,7	40,5	39,0	26,3	16,7	23,6	11,7	10,3	13,9	11,9	3,9	2,7	36,1	28,2	17,8	23,3	13,5	28.128,9
Greece	42,4	57,7	29,1	26,3	28,5	16,0	31,5	42,9	8,4	7,9	3,1	5,3	0,8	0,6	38,8	27,5	17,3	15,8	10,4	22.380,9
Ireland	28,1	42,7	28,9	33,7	42,9	23,6	21,3	33,9	8,2	6,9	16,8	8,9	14,6	2,3	24,5	27,0	14,6	20,9	10,9	34.300,3
Italy	31,9	40,7	32,3	35,8	35,8	23,4	22,8	34,7	10,2	8,9	11,1	10,7	2,2	1,9	38,1	26,8	15,6	16,8	10,4	26.419,7
Japan	31,1	53,0	34,2	30,6	34,7	16,4	23,5	44,6	10,3	7,1	8,0	8,5	2,7	2,0	44,7	30,3	10,8	7,4	12,7	27.221,9
Korea	19,2	52,0	64,9	29,2	15,8	18,7	24,2	40,6	17,1	7,0	9,5	9,4	3,7	2,4	32,1	30,8	13,3	9,8	10,8	18.607,1
Netherlands	26,7	32,0	39,9	40,3	33,4	27,7	19,0	24,3	10,7	6,1	9,0	9,7	2,7	2,0	37,8	34,0	20,8	24,0	12,3	31.705,6
Norway	7,9	33,4	65,8	41,8	26,4	24,9	15,4	23,8	27,2	9,1	6,5	7,9	1,1	1,0	31,2	29,1	18,6	29,1	12,3	42.761,4
Portugal	34,2	49,8	36,8	33,3	29,1	16,9	24,9	41,8	9,9	7,7	4,6	4,1	1,4	1,4	35,7	24,8	23,5	20,3	8,0	18.739,7
Spain	10,2	47,4	78,2	34,2	11,6	18,5	30,4	37,6	10,5	8,6	7,1	5,9	2,2	1,4	33,5	27,0	16,3	19,4	9,7	24.956,5
Sweden	21,2	28,2	41,1	44,9	37,7	26,9	18,4	24,3	10,6	7,9	11,9	11,0	3,1	1,6	34,0	25,2	21,9	30,0	12,0	29.250,9
Taiwan	26,9	42,6	42,2	39,9	30,9	17,5	15,3	30,9	12,3	8,9	10,7	12,9	3,1	2,9	43,9	31,7	14,7	12,8	8,8	22.392,9
UK	27,0	36,6	33,2	33,6	39,8	29,9	20,3	26,4	9,7	6,5	11,7	9,3	2,1	1,4	39,2	34,6	17,1	21,8	12,1	28.504,4
US	23,5	33,4	38,5	36,0	38,0	30,6	16,1	24,4	9,0	6,2	10,7	9,1	2,2	1,2	40,3	31,9	21,7	27,3	13,1	37.685,0
Average	**26,2**	**40,0**	**40,9**	**36,4**	**32,9**	**23,6**	**20,9**	**30,6**	**11,6**	**7,8**	**9,9**	**9,1**	**2,9**	**1,7**	**36,7**	**29,6**	**18,0**	**21,2**	**11,6**	**28.634,1**
Std. Dev.	**7,8**	**8,4**	**12,8**	**4,8**	**7,6**	**4,8**	**4,6**	**7,5**	**4,3**	**1,1**	**3,4**	**2,1**	**2,8**	**0,6**	**4,5**	**3,1**	**3,4**	**6,3**	**1,5**	**5.678,3**
Max.	**42,4**	**57,7**	**78,2**	**44,9**	**42,9**	**30,6**	**31,5**	**44,6**	**27,2**	**10,3**	**16,8**	**12,9**	**14,6**	**2,9**	**44,7**	**34,6**	**23,5**	**30,0**	**13,5**	**42.761,4**
Min.	**7,9**	**28,2**	**28,9**	**26,3**	**11,6**	**16,0**	**14,9**	**19,5**	**8,2**	**6,1**	**3,1**	**4,1**	**0,8**	**0,6**	**24,5**	**24,8**	**10,8**	**7,4**	**8,0**	**18.607,1**

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