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Abstract

Casual evidence suggests that emerging and developing countries are often gaining market shares in world exports in technology-intensive sectors in the course of development. On the other hand textbook trade theory would suggest that these countries specialize in lower-tech industries. The reason for this is the assumption that the technology gap in these industries is lower and thus under the further assumption of equal wage rates across industries the developing countries have a comparative advantage in the lower-tech industries. In this paper we take a dynamic view on development and trade integration and distinguish three types of catching-up processes (the 'continuous convergence approach', the 'climbing up the ladder approach' and the 'jumping-up approach'.) Using data for 25 countries and 32 industries we empirically analyse the different patterns of catching up over the period from 1981 to 1997. Further we discuss linkages between technological convergence, dynamics of comparative advantage and trade patterns.

JEL-Classification: F14, L6, O10, O14, O30, O41

Keywords: catching up, dynamics of comparative advantage, trade and technology

Contents

TECHNOLOGICAL CONVERGENCE AND TRADE PATTERNS

Robert Stehrer and Julia Wörz[1]

1 Introduction

In principle there are three possible scenarios with respect to technological catch-up. The first one assumes catching-up to be equally rapid in all industries. Thus, the lagging country improves its technology in all sectors at such a rate that the gap to the leading country is closed across all industries at the same speed. This scenario is the one modelled e.g. by Krugman (1986) in the context of international trade. We refer to this approach as the 'continuous convergence approach'.

In a second scenario catch-up will take place in the low-tech industries first, and only when the initial gap in those industries is closed (or has reached a threshold level) the lagging country starts to close the gap in the next more technology-intensive industries. This could be referred to as 'climbing up the ladder' by the follower country.

However, a third possibility may also be relevant, namely that lagging countries catch up in high-tech or fast growing industries first, closing the gap to the leader faster in these sectors. This pattern might occur because of the higher learning potential in these sectors which reflects Gerschenkron's idea of the 'advantage of backwardness' (Gerschenkron, 1952) at the industrial level, higher expected returns on investment or higher profit rates and higher expected (world) growth rates. To this approach we shall refer as the 'jumping-up approach'.

Further there are some other industry characteristics that have to be taken into account. In the model by Fujita et al. (1999), Chapter 15, it is shown that, first, industries

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spread to countries not simultaneously but sequentially. Thus the process of industrialization is not uniform across countries but different countries undergo rapid industrialization in a series of waves. Second, in this model the most labour-intensive industries are first 'going south' because of high labour costs. Third, and even more interesting for this paper, the less labour-intensive industries enter the world markets more rapidly than the labour-intensive ones due to forward and backward linkages in the model. It is further shown that other industry characteristics can also be important (e.g. 'sales orientation', 'industries with low intermediate input requirements', 'upstream industries', and 'strongly linked industries').

Especially for small open economies the prevailing type of catch-up will certainly have an influence on the pattern of trade. For example, under the third scenario, export growth should be highest in the high-tech industries. The reason for a technologically backward economy to move directly from the production of low-tech goods to high-tech ones is likely to be found in the presence of unexploited market niches in world demand for high-tech, but reasonably priced goods. By surpassing intermediate steps in development and by educating the labour force explicitly to serve those needs, it is possible to keep wages low even in high-skill-intensive industries. At the same time, domestic demand will develop more slowly in the sense that demand for higher-tech goods will rise only after lower-tech goods have been consumed. Thus, the bulk of high-tech production will be for the export market. For the rapidly industrializing East Asian economies one would expect to find evidence for this third pattern of catch-up. In consequence, we would also expect to see this pattern being reflected in the development of corresponding trade patterns.

2 Technological catching-up and trade performance

In the literature there are different approaches concerning the trajectories of economies when being integrated into the world markets.

The first approach to catching-up is known in the literature under different headings. In general this approach implies that countries or industries that are lagging further

behind the leader experience relatively higher growth rates of productivity. This goes back to the idea of the 'advantage of backwardness' introduced byGerschenkron (1952) which has been formalized at the country level in the neoclassical growth literature (see e.g. Barro and Sala-i-Martin, 1995, for an overview). At the more disaggregated level a similar pattern of catching-up is discussed in Krugman (1986). In this model it is assumed that the relative gap is larger in industries with high-technology intensity measured by the growth rate of technical progress in the leader country which gives an unambiguous ranking of industries. For the catching-up countries it is assumed that the technology gap measured by the time lag is reduced at equal rates across industries which leads to the pattern that industries lagging further behind experience higher productivity growth rates. The ranking of industries with respect to relative gaps remains, however, the same over time. As the wage rate is assumed to be equal across sectors, this implies that sectors at the edge (i.e. where unit costs are equal in the North and the South) are lost in the Northern economies as the Southern countries gain comparative advantage in these sectors.

The second may be classified as the 'ladder approach'. In this approach it is assumed that developing countries are climbing up a 'ladder' with respect to the technology gaps of their industries (relative to leader countries). In the beginning these countries are expected to have their comparative advantages in the lower-tech industries. Catch-up will take place in the low-tech industries first, and only when the initial gap in those industries has been closed (or has reached a threshold level) the lagging country speeds up the closure of the gap in the next more technology-intensive industries. The countries are thus taking over the more sophisticated branches only 'step by step' or 'climbing up a ladder'. The difference to the pattern in the first approach is that it is assumed that countries undergo a specific pattern of development stages to be able to compete in the higher-tech sectors, whereas in the first pattern the development process takes place in all industries simultaneously. Thus, the countries are gaining comparative advantages in the medium-low-technology sectors, then in the medium-high- technology sectors, and so on. The more advanced countries are thus losing more and more industries to the

developing countries. This pattern of shifts in the trade structures is also reflected in the debate on labour market outcomes of trade integration. As more and more low-tech industries (which are assumed to be low-skill-intensive) are lost to the catching-up countries, demand for low-skilled workers in advanced countries is shrinking and thus relative wages are declining.

Finally there is at least casual evidence that a number of countries are rapidly catching up in higher-tech industries and gaining comparative advantages in these industries. This pattern of catching-up and the corresponding shifts in comparative advantages are hardly debated. At least some reasons can be given why this pattern might occur. A simple argument is the following: There might be an incentive for a firm to invest in a country in a good for which the country has a comparative disadvantage as the decision depends on the difference between world price and unit costs.[2] Further there are some other reasons why a country may gain comparative advantages in the higher-tech industries: First, if the initial gap is higher in industries that have a higher learning potential converge may be faster in these industries. Second, the sector-specific learning curves may differ across industries due to industrial policy which promotes specific sectors. Third, vintage effects make it easier for newly industrializing countries to have higher shares of recent vintages in their capital stock. And, fourth, wage rates (or growth in wage rates) may differ across industries which give rise to gains in unit labour costs. Thus, industries showing a higher rate of technological progress may have wage growth below their rate of productivity increases and thus are gaining comparative advantages in higher-tech branches. Finally, there is an incentive to invest in sectors where the expected (world) growth rates are high as it is easier to gain market shares in fast growing markets than in slow growing or even declining ones. In general, all these factors mean that countries do not necessarily specialize in industries in which they have a comparative advantage in the beginning but

[2]Consider a specific numerical example: Suppose the world prices are given by $p_1^w = 4$ and $p_2^w = 2$ whereas the country-specific cost prices are $p_1^c = 2.5$ and $p_2^c = 1$, respectively. It is clear that the country has a comparative advantage in sector 2 as $\frac{p_1^w}{p_2^w} = \frac{4}{2} < \frac{p_1^c}{p_2^c} = \frac{2.5}{1}$. Producing good 1 and exporting to the world market (where we make a small country assumption, i.e. prices remain stable) yields that per unit profit is 1.5 for good 1 but only 1 for good 2.

'jump up' in specific industries for which e.g. expected per unit profits or gains in market shares are highest.

In this paper we provide evidence that this third pattern of technological convergence and shifts in the pattern of trade are a more relevant scenario at least for some countries or country groups than the more traditional view of 'climbing up the ladder' (the second scenario) or the first scenario of 'continuous' convergence. Further we discuss the evidence for the relevance of these patterns of technological catching-up for the emergence of trade structures.

3 Data

One of the problems in analysing the production and trade performance of a large country group including East Asian and Latin American countries[3] is, first, to get comparable data for the production side of these countries and, second, to combine these data with trade data. For the list of countries included in the analysis see table A.1 in the appendix. We aggregated the countries into three groups: OECD-North (generally without the US), OECD-South (Greece, Iceland, Portugal and Spain) and East Asian countries (Hong Kong, Indonesia, Korea, Malaysia, Singapore and Thailand).

For the production side we use data from the UNIDO Industrial Database at the ISIC, revision 2, 3-digit, and for particular industries at the 4-digit level, again from the UNIDO Industrial Database, revision 2, 4-digit. For a list of the 32 included industries see table A.2 in the appendix. The UNIDO data have the advantage of including a large country sample at this rather disaggregated level. On the other hand, these data are problematic with respect to the quality of the data. For this reason we have cross-checked the data for outliers and breaks in the time series. From this UNIDO database we use data generally from 1981 to 1997 but with differences in availability across countries and industries.

Trade data are taken from the UNIDO Industrial Demand Supply Balance Database which provides data for 74 countries at the ISIC, revision 2, 4-digit level covering the

[3] In this paper we do not refer to the Latin American countries.

period 1981 to 1998 (coverage may differ from country to country). These data are available in US-$. We used exchange rates from the IFS statistics to convert the data into NCU and then expressed all data at current Purchasing Power Parities (PPP) using the PPP rates from the World Bank. Note that the data are expressed at current prices and are converted at current purchasing power parities (see Landesmann and Stehrer, 2001, where this issue is discussed in more detail).

We further use some aggregations of the data with respect to industry-specific characteristics. In this paper we matched the classification given in Hatzichronoglou (1997) where four classes of industries (low-technology, medium-low-technology, medium-high-technology, and high-technology) are distinguished (see again table A.2 in the appendix for the classification of industries).

4 Patterns of convergence

In this section we give a descriptive analysis of the data. Because of the quality of the data and the high level of aggregation used, this overview has to be interpreted with some caution and serves as a first illustrative view at important trends. We calculated the initial gaps in output productivity, wage rates and unit labour costs relative to the US and the growth rates of these variables. After the analysis of gaps and growth rates we further describe trade structures. The data are summarized over countries by country groups and over industries for the four types of industries mentioned above. Thus the results presented below are weighted averages over countries and groupings of industries.

We choose the US as the leader given its relative position in the world economy. This choice is further confirmed by a few facts emerging from the data: First, output productivity is on average highest in the US. Although Japan also shows a high level of output productivity it has not overtaken the US as a technology leader in general (although this might be the case in some industries).

4.1 Descriptive analysis

The gaps and growth rates of output productivity, wages and unit labour costs are summarized in table 4.1. In this table we calculated weighted averages of the respective variables for each country and industry group.

4.1.1 Productivity

On the technology side we first calculated the initial gaps of labour productivity (output per employee) for the four types of industries relative to the US level for the Northern OECD countries (without US), the Southern OECD countries and the East Asian countries in 1981. Table 4.1 reports the initial gaps in percentages of the US level. The productivity levels in the OECD-North countries ranged from 65 per cent in the high-tech sectors to about 75 per cent in the low-tech sectors in 1981. Thus the gap is higher in the higher-tech sectors. This can be compared to the OECD-South countries where the levels are lower in general, ranging from 68 per cent in the low-tech sectors to 63 per cent in the medium-high-tech sectors. Thus again the gaps are larger in the higher-tech sectors. The exception to this are the high-tech sectors where the OECD-South countries show a level of about 74 per cent (which is even higher than in the OECD-North countries). For this pattern to be explained it should be noted that this group of industries includes only four industries.[4] The East Asian countries show, however, a different pattern of initial gaps. First, the gaps are generally higher than in the OECD-South countries. Second, the gaps are higher in the lower-tech sectors than in the higher-tech sectors as the levels range from 38 per cent in the low-tech to 47 per cent in the high-tech sector.

With respect to the growth rates the OECD-North and OECD-South countries show a similar pattern where, in general, the growth rates are higher in the higher-tech sectors. The only exception is again the high-tech sector where the OECD-South countries only have a growth rate of 3.6 per cent. The growth rates for the East Asian countries are higher in all industry groups and are highest in the higher-tech sectors. Compared to the

[4]Specifically, Spain shows quite high productivity levels in industry 3825 (Office, Computing and Accounting Machinery) and 3832 (Radio, TV, and Communication Equipment and Apparatus).

Table 4.1: Descriptive statistics

	Initial Gap[a]			Growth rate[b]			
Productivity	**OECD-North**	**OECD-South**	**East Asia**	**OECD-North**	**OECD-South**	**East Asia**	**US**
Low tech	76.61	68.20	38.28	4.62	4.06	5.88	4.71
Medium low	70.10	66.33	40.12	3.83	2.82	6.02	2.94
Medium high	72.77	63.42	46.53	7.17	6.75	8.38	5.80
High	65.33	74.16	47.34	12.46	3.57	9.82	8.44
Wages	**Initial Gap[a]**			**Growth rate[b]**			
	OECD-North	**OECD-South**	**East Asia**	**OECD-North**	**OECD-South**	**East Asia**	**US**
Low tech	83.78	60.44	23.35	2.83	2.55	5.51	4.03
Medium low	73.36	61.91	24.71	2.59	2.84	6.34	3.42
Medium high	68.92	62.41	24.64	3.95	3.09	7.72	4.57
High	66.17	60.82	19.28	8.83	1.55	6.79	5.17
Unit labour costs	**Initial Gap[a]**			**Growth rate[b]**			
	OECD-North	**OECD-South**	**East Asia**	**OECD-North**	**OECD-South**	**East Asia**	**US**
Low tech	109.35	88.63	61.00	-1.78	-1.51	-0.37	-0.68
Medium low	104.65	93.33	61.60	-1.24	0.02	0.31	0.48
Medium high	94.70	98.40	52.94	-3.22	-3.66	-0.66	-1.23
High	101.29	82.01	40.72	-3.62	-1.24	-3.02	-3.27

[a] US=100

[b] per annum growth rates in per cent

US growth rates the OECD-North and the East Asian countries show higher growth rates than the US, the OECD-South countries only in the medium-high-tech sectors.

4.1.2 Wage rates

For the OECD-North countries the initial gaps in the wage rates correspond more or less to the structure of the gaps in productivity levels although the gaps are somewhat smaller. For the OECD-South countries the gaps are higher and are almost equal in all groups of industries. In the East Asian countries the gaps are again similar across the industry groups (although higher in the high-tech sectors) and are at an even lower level of about 20 to 25 per cent. Especially for the latter group of countries low levels of wages are found in the high-tech sectors which, as already mentioned above, have the smallest gap in productivity levels. As regards the growth rates the OECD-North countries exhibit growth rates of about 2.5 to 4 per cent in the low-, medium-low- and medium-high-tech sectors and 8 per cent in the high-tech industries. The growth rates in the OECD-South countries are on average between 2.5 and 3 per cent and only 1.5 per cent in the high-tech industries. The growth rates are higher in the East Asian countries, ranging from 5.5 in the low-tech to 7.7 per cent in the medium-high-tech sectors.

4.1.3 Unit labour costs

The comparative (labour cost) advantages[5] are determined jointly by productivity levels and wage rates (which may differ across sectors). The highest initial unit labour costs (relative to the US) for the OECD-North countries are in the low-tech and medium-low-tech sectors and lowest in the medium-high-tech sectors. This pattern is mainly caused by the relatively low wages in these sectors which compensate for the low productivity levels. For the OECD-South countries the unit labour costs are highest (relative to the US) in the medium-low- and medium-high-tech industries. For the East Asian countries the gap in unit labour costs is highest in the medium-high- and high-tech industries due to relatively low gaps in productivity and high gaps in wage rates.

[5]For data reasons we were not able to take account of any other costs than labour costs.

Unit labour costs are falling faster in the OECD-North countries than in the US. The differences in growth rates are highest in the medium-low- and medium-high-tech sectors and lowest in the high-tech sectors. The OECD-South countries are gaining competitiveness in all but the high-tech sectors. The East Asian countries lose competitiveness in all but the medium-low-tech sectors, although the differences in growth rates are quite small. This means that the structure of the relative levels of unit labour costs remained almost constant in this period and thus the East Asian countries maintained their pattern of being more competitive in the higher-tech sectors as described above.

4.1.4 Trade structures

The trade structures follow the expected pattern based on casual evidence. Table 4.2 presents the export shares in total exports of the different country groups (export structures). The East Asian countries have changed their trading structure and now export more in the medium-high- and high-tech industries than in the other industry groups (and thus reversed the pattern given in 1981). Although a similar pattern can be found for the OECD countries it is not as pronounced as for the East Asian countries. Table 4.2 presents the export shares in total (world) exports. Here again one can see that the East Asian countries, although gaining in all industries, are gaining most rapidly in the high-tech industries. On the other side, the OECD-South countries have a stronger pressure in world markets in the low- and medium-low-tech industries.

4.2 Theoretical assumptions revisited

Krugman's concept of a 'ladder of countries' described above relies on two crucial assumptions. First, countries can be ranked unambiguously by technology level such that higher ranked countries always have an absolute comparative advantage in all sectors over lower ranked countries. This assumption permits the use of the notion of a 'ladder of countries'. Second, it is assumed that sectors can be ranked such that the productivity advantages of higher ranked countries is increasing in this technology ranking of sectors. Thus, the ladder of countries is accompanied by a unique technology ranking of goods.

	US		OECD-North		OECD-South		East Asia	
	1981	**1997**	**1981**	**1997**	**1981**	**1997**	**1981**	**1997**
Shares in total imports by country groups								
Low tech	23.06	19.81	32.43	38.22	20.09	43.03	27.36	22.28
Medium low	28.41	17.68	29.83	27.29	25.83	32.28	22.77	29.74
Medium high	36.16	38.77	31.27	30.15	43.73	24.69	38.58	32.52
High	12.37	23.74	6.46	4.33	10.36	12.55[a]	11.29	15.47
Shares in total exports by country groups								
Low tech	15.42	13.81	33.12	32.15	33.76	46.12	33.72	21.77
Medium low	13.71	11.88	34.27	29.66	35.19	41.00	32.70	23.94
Medium high	49.73	46.08	28.55	34.97	27.15	12.87	17.86	24.91
High	21.14	28.23	4.05	3.22	3.90	6.99[a]	15.72	29.38
Shares in total world imports by industry groups								
Low tech	22.95	31.46	65.55	48.37	3.18	5.81	8.32	14.35
Medium low	28.39	32.59	60.55	40.10	4.10	5.06	6.95	22.25
Medium high	30.54	49.64	53.63	30.77	5.87	2.69	9.96	16.90
High	40.44	70.92	42.90	10.32	5.38	4.18[a]	11.28	18.76
Shares in total world exports by industry groups								
Low tech	15.70	23.41	73.86	54.81	4.81	7.67	5.63	14.11
Medium low	13.84	21.66	75.77	54.35	4.97	7.33	5.41	16.67
Medium high	41.80	50.07	52.55	38.21	3.19	1.37	2.46	10.34
High	63.80	66.12	26.78	7.59	1.65	1.26[a]	7.78	26.30

[a] Data for 1992

Table 4.2: Trade patterns

A first analysis of the data, however, does not suggest that we can talk of a ladder of countries or a generally valid ranking of industries in the case of the rapidly catching-up East Asian countries. Assuming that there is only one factor of production, namely labour, increased productivity will mirror technological progress. With the US as the leader country we expect to find high correlations in industry productivity growth rates in the US and the remaining countries in our sample under both, the first and the second scenario. Simple correlation measures lead us to conclude that technological progress in the East Asian countries is not correlated by the US and more influenced by Japan. Further, among the East Asian countries, sectoral productivity growth rates are in most cases independent, although three pairs of countries emerge. Korea and Hong Kong, Singapore and Indonesia, and Malaysia and Thailand each show a similar sectoral pattern of technological progress. Ranking industries by their productivity growth rates and calculating rank correlations reconfirms that the sectors with fast productivity increase vary considerably across countries and catch-up takes place at different speeds in different sectors. Thus, the first and the second scenario of technological catch-up are both not supported by this first casual look at the data.[6]

Under the third scenario, productivity growth in the follower should be substantially higher in the high-tech sectors compared to the leader (even if one takes the different levels of the productivity gap in the initial period into account). It has already been mentioned above that the East Asian countries are characterized by high productivity growth rates in only a few sectors, whereas the US exhibits a more balanced pattern of growth. This phenomenon should be analysed in detail in the section below.

4.3 Patterns of technological catching-up

In this subsection we look at typical patterns of technological change across industries. Here we use an approach which is usually applied in aggregate growth studies (see, however, Landesmann and Stehrer (2001) for an application of this approach at the industrial

[6]For a detailed analysis of the development of East Asian manufacturing see Timmer (2000).

level). We defined the initial gap at time $t = 0$ as

$$G^c_{i,0} = \ln \frac{v^c_{i,0}}{v^{US}_{i,0}}$$

where $G^c_{i,0}$ denotes the gap of the respective variable v^c_i for country c in industry i and estimated a catching-up equation denoted by

$$\gamma^c_i = \sum_{j,g} \beta^g_j D^g_j G^c_{i,0} + \sum_c \delta^c D^c + \sum_i \delta_i D_i + \varepsilon^c_i$$

where γ^c_i denotes the growth rate of the respective variable for country c in industry i.[7] Catch-up is measured by regressing the growth rate on the initial gap of the respective variable. In order to get a coherent picture about the competitiveness of a country, the same specification was used to test for catching-up in wage rates and unit labour costs. D^g_j denotes a set of dummy variables for each industry group j in country group g. This first set of variables $D^g_j G^c_{i,0}$ allows for different slope parameters β^g_j according to country and industry group. A significantly negative coefficient indicates that productivity growth (or growth of wages or unit labour costs, respectively) is higher the higher the initial gap for this country group in the respective industry group. In most cases this means that the country is further behind. In such a case we speak of convergence for the group of countries g in the respective industry segment t. For each of the three scenarios outlined above, we expect a different pattern of catching-up or convergence according to technology intensity. For example, under the 'continuous convergence approach', the catch-up parameters in all four classes should be roughly equal, implying equal convergence in all industries. Under the 'ladder approach', catch-up will be faster in lower-tech sectors first, thus convergence is expected to be stronger in these industries. The 'jumping-up approach' allows for various patterns. In the case of East Asia, we would expect technological convergence to be strongest in high-tech sectors. The coefficients δ^c and δ_i indicate the presence of individual industry and country (fixed) effects denoted by the dummy variables D^c and D_j, respectively.

The results for convergence in productivity, controlling for industry- and country-specific effects, are presented in the first column of table 4.3. Indeed, Asia shows signifi-

[7] The growth rates were calculated as a linear trend of the logarithmic variables over the whole period.

Country group	**Industry group**	**Productivity**	**Wages**	**Unit labour costs**
OECD-North	Low	-0.023	-0.025	-0.024
		(0.000)	(0.001)	(0.000)
	Medium Low	-0.030	-0.023	-0.025
		(0.000)	(0.001)	(0.000)
	Medium High	-0.003	0.000	-0.018
		(0.683)	(0.981)	(0.007)
	High	0.011	-0.005	-0.014
		(0.306)	(0.577)	(0.267)
OECD-South	Low	-0.018	-0.039	-0.011
		(0.019)	(0.000)	(0.165)
	Medium Low	-0.039	-0.037	-0.022
		(0.000)	(0.000)	(0.003)
	Medium High	-0.007	-0.027	-0.005
		(0.417)	(0.000)	(0.757)
	High	0.007	-0.030	-0.017
		(0.548)	(0.001)	(0.091)
East Asia	Low	-0.010	-0.016	-0.032
		(0.028)	(0.003)	(0.000)
	Medium Low	-0.028	-0.018	-0.030
		(0.000)	(0.000)	(0.000)
	Medium High	-0.027	-0.018	-0.007
		(0.000)	(0.001)	(0.242)
	High	-0.013	-0.017	-0.008
		(0.102)	(0.003)	(0.119)
$\bar{R}^2$		0.89	0.93	0.50
F		79.22	132.94	10.83
Obs.		644	645	649

Table 4.3: Convergence parameters (p-values in brackets)

cant convergence in all industries with the exception of the high-tech industries. Convergence parameters are highest in the medium-low- and medium-high-tech industries. We also found a negative (although not significant) coefficient for the high-tech industries. The other two country groups show convergence only in the low- and medium-low-tech industries.

In high-tech industries no convergence to the leader is found. All countries converge to the US in medium-low-tech and low-tech industries, but convergence is stronger in OECD countries compared to East Asian countries.

The results in combination with those on wage rates reveal a clear competitive advantage for the East Asian countries in the medium-high-tech industries. With respect to wages, these countries do not only start from a considerably lower level in all industries, but also convergence to the US level is slower than for both groups of OECD countries (especially than for the Southern OECD countries). Thus, although wages are rising in all industries, the East Asian countries have managed to retain their initial cost advantage longer than the group of catching-up countries within the OECD. The latter group shows significant convergence in wage levels in all industries and at rates nearly twice as high.

The picture is completed by looking at the evolution of unit labour costs contingent on the initial gap (see column 3 of table 4.3). East Asia converges fast in the low-tech and medium-low-tech industries, implying rising unit labour costs and thus worsening its competitiveness in those industries. No convergence in the medium-high-tech and high-tech industries indicates that the initially low level of unit labour costs versus the US has been maintained over the observation period. The advanced OECD countries show similar coefficients, but depending on the initial conditions we have to interpret them differently. In the low-tech and medium-low-tech industries convergence takes place from a higher initial level towards the lower US level (see table 4.1) and thus reflects increased competitiveness. In the medium-high-tech industries unit labour costs have fallen significantly from a level slightly below that of the US to a much lower level. Thus, competitiveness has also improved for these countries in the medium-high-tech category.

The catch-up patterns on the production side show only subtle differences among the

three groups of countries. In general, technological catch-up takes place in the lower-tech industries, with the exception of East Asia. Those countries are the only ones which converge in productivity levels in medium-high-tech industries while keeping unit labour costs relatively low. Wages catch up in all industries and in all countries, but convergence is slower in East Asia and starts from a lower initial level. The evolution of unit labour costs shows that the Northern OECD countries gain competitiveness in the low- and medium-tech segment, whereas East Asian countries gain most in the medium-high- and high-tech industries. The picture is rather mixed for the Southern OECD countries: Generally, these economies lose competitiveness in the medium-low- and high-tech industries, gaining in the low- and medium-high-tech categories.

5 Convergence and trade patterns

5.1 Dynamics of trade patterns

Given these results, we expect to find corresponding developments in trade patterns. In other words, the analysis of revealed comparative advantages should reflect the competitiveness of individual regional groups in different industry groups as outlined above. The general discussion of exports and imports in this subsection is followed by an analysis of convergence and specialization patterns in net exports. The ranking of industries within each country according to their export orientation has remained stable: industries with a high export market share in the initial phase are also those with the highest share at the end of the period. An analysis of the evolution of revealed comparative advantages (RCAs) gives further insights. The RCA was calculated as[8]

$$RCA_i^c = \frac{X_i^c / X_-^c}{X_i^- / X_-^-} - \frac{M_i^c / M_-^c}{M_i^- / M_-^-}$$

X and M denote exports and imports, i denotes the industry, c is the country and $-$ denotes world minus country c and total manufacturing minus industry i, respectively. Table 5.1 shows the RCAs for the four types of industries and the three country groups

[8]For an overview of various RCA measures see Vollrath (1991).

	Exports		Imports		RCA	
	1981	**1997**	**1981**	**1997**	**1981**	**1997**
			Low tech industries			
US	0.553	0.582	0.938	0.958	-0.384	-0.375
OECD North	0.976	0.839	1.289	1.388	-0.312	-0.549
OECD South	1.962	1.929	0.676	1.027	1.286	0.902
East Asia	2.324	1.561	0.777	0.620	1.546	0.942
			Medium low tech industries			
US	0.412	0.610	1.138	0.933	-0.726	-0.323
OECD North	1.424	1.172	0.885	0.938	0.539	0.234
OECD South	1.639	1.581	0.955	1.005	0.685	0.576
East Asia	1.525	0.982	1.084	1.165	0.441	-0.184
			Medium high tech industries			
US	1.590	1.282	0.865	0.937	0.726	0.345
OECD North	1.089	1.602	1.020	0.978	0.069	0.624
OECD South	0.489	0.858	1.438	1.423	-0.948	-0.565
East Asia	0.239	0.341	0.984	0.947	-0.745	-0.606
			High tech industries			
US	2.704	1.543	1.225	1.211	1.479	0.332
OECD North	0.483	0.540	0.762	0.795	-0.279	-0.255
OECD South	0.287	0.242	0.850	0.521	-0.562	-0.279
East Asia	1.144	2.275	1.353	1.411	-0.208	0.864

Table 5.1: Revealed comparative advantages and components

plus the US. The relative net positions of all three regional blocks and the US have changed considerably over the observation period. Two general features emerge from the table. First, all country groups have lost in categories where they were initially holding a strong position. This has even led to switchovers in comparative advantages for the group of East Asian countries. Second, the importance of low-tech industries has declined in the sample as a whole, implying losses in net export shares for all three groups.

The US started with a revealed comparative advantage in the medium-high-tech and high-tech industries, but the RCAs have become lower in both categories, especially so in the high-tech segment. This was mainly due to changes in the export component, while the import component remained almost stable. Imports were reduced in the medium-low-

tech industries leading to an improvement of their world market position in this category.

The Northern OECD countries were initially characterized by comparative advantages in the medium-low- and medium-high-tech industries. Their position in the medium-low-tech industries worsened while they boosted exports in the medium-high-tech category, thus improving their world market position in this segment.

Both groups of catching-up countries started with a relatively strong position in the low- and medium-low-tech industries. Whereas the OECD-South countries lost this comparative advantage mainly because imports increased, the East Asian countries diverted exports successfully towards higher-tech industries. In East Asia exports in the low- and medium-low-tech categories dropped considerably while high-tech exports increased sharply, leading to a reversal in these countries' net export position from a net importer of high-tech goods to a net exporter. The group of East Asian countries shows a very dynamic trade pattern with another switchover from a positive to a negative RCA in the medium-low-tech industries.

In summary, the strong competitive position of the technology leader in high-tech industries has been eroded most strongly by the group of East Asian countries. However, the RCA as it is reported does not allow to discriminate between improvements due to relative gains in market share by a country and absolute gains of the respective industry worldwide. The group of East Asian countries shows the strongest export growth in all industries, thus taking market shares from all other countries. In the medium-high-tech industries to some extent also the Northern OECD countries have gained strength at the expense of the US. The Southern OECD countries have also gained some strength due to rising exports in the medium-high-tech industries, but they are still a net importer of goods in high- and medium-high-tech industries.

Looking at individual countries, the most apparent changes in RCA have taken place in the high-tech segment (results not reported). Here, the majority of countries showed considerable improvements in their net trade position relative to the sample as a whole. Great Britain, Sweden, Indonesia, Malaysia, Singapore and Thailand switched from a revealed comparative disadvantage in the high-tech sector to obtaining a comparative

advantage. The high number of East Asian countries among those suggests that the third scenario of technological catch-up, the 'jumping-up approach', may be appropriate to describe this group. The OECD catch-up countries in the sample also show moderate improvements in the high-tech sectors, but even more pronounced in the medium-high-tech industries. The second catch-up scenario ('climbing up the ladder') seems to be more appropriate to describe their position in the world market. The 'leader' countries US and Japan are, besides the Netherlands, Portugal and Hong Kong, the only ones who lost competitive strength in the high-tech segment. Thus, catching-up has taken place at the expense of the leading countries primarily.

In the low-tech sectors only very few countries have gained competitiveness, measured as the net effect of relative export to relative import performance in the specific country. These countries are scattered over all three regional blocks and not identical with classical backward countries - quite on the contrary. Austria, France, Italy, the Netherlands, Great Britain, the US, Greece, Hong Kong and Indonesia have improved their RCAs in low-tech industries.

The RCA measures can be used to investigate specialization and convergence patterns in a comparative-static framework. In order to test whether country groups have retained a stable trade pattern across sectors the following simple regression model is used

$$RCA^c_{i,T} = \alpha + \beta RCA^c_{i,0} + \varepsilon^c_i$$

which was estimated separately for each country group. (See Laursen (2000) for a discussion of this formulation.) The coefficient β indicates whether or not existing specialization patterns have been reinforced over the whole period. A $\beta = 1$ indicates an unchanged pattern over the whole period, a $\beta > 1$ hints towards rising specialization, i.e. a country has gained comparative advantage in sectors where it has been specialized already and vice versa. If the coefficient lies between zero and one, de-specialization is present and if $\beta < 0$ the specialization pattern is either completely reversed or purely random over time. In all three groups of countries, de-specialization can be observed, i.e. trade patterns have become less pronounced. This trend of diminishing dependence on just a few sectors is strongest in East Asia and weakest in the OECD-South (see table 5.2). Thus, the East

	OECD-North	**OECD-South**	**East Asia**
Coefficient	0.4036	0.6469	0.3610
F ($H_0 : \beta_i = 0$)	0.0000	0.0000	0.0010
F ($H_0 : \beta_i = 1$)	0.0000	0.0000	0.0000
R^2	40.95	76.49	29.46

	Low	**Medium low**	**Medium high**	**High**
Coefficient	0.1083	0.2442	0.6771	0.0750
F ($H_0 : \beta_i = 0$)	0.0020	0.1550	0.0000	0.7480
F ($H_0 : \beta_i = 1$)	0.0000	0.0001	0.0020	0.0006
R^2	34.05	8.57	70.00	0.46

Table 5.2: Specialisation and convergence patterns in trade structures

Asian countries have broadened their export base best, they managed to gain comparative advantages in sectors with low initial specialization and shifted away from sectors with high initial specialization. The trade performance of the Southern OECD countries has remained more traditional, although the overall trend of de-specialization is also present.

Analogously, a similar analysis can be used to look at convergence across countries within a specific sector. The regression equation is similar to the one above, but run across countries and separately for each sector.

$$RCA^c_{i,T} = \alpha + \beta RCA^c_{i,0} + \varepsilon^c_i$$

estimated separately for each industry group. Results are also presented in table 5.2. The results vary greatly across industry groups. Whereas strong convergence is found in the low-tech and some convergence in the medium-high-tech sectors, no clear-cut conclusions can be drawn with respect to the medium-low-tech and high-tech sectors. In both cases the coefficient does not differ statistically from zero, which does not allow to draw any firm conclusions. A detailed look at individual industries in the high-tech segment (not reported here) reveals that there has been no change in the drugs and medicine industry and in the radio, TV and communication industry. However, trade patterns across countries have converged in the office, computing and accounting machinery industry and even more so in manufacture of aircraft.

The dominating trends lead towards more equal and less pronounced trade specialization patterns and more homogeneous partners in international trade. The RCAs confirm the differences in the kinds of catch-up scenario which are appropriate for the two groups of lagging countries. Whereas the Southern OECD countries have in principle retained their traditional position of being competitive in low-tech industries and having a weak world market position in high-tech industries (with continuous movements towards improving their situation in the high-tech group at the cost of deteriorating strength in the low-tech segment), the East Asian countries establish themselves as being highly competitive in high-tech goods at the cost of the US and also the group of OECD-North countries.

5.2 Is there a link?

If there is a link between trade performance and technological catch-up, we would expect to find that the specific catch-up scenario will influence the pattern of trade and its development. Under the first scenario, competitiveness as revealed by imports and exports should grow homogenously across industries. Under the 'climbing up the ladder' scenario, relative net market shares are expected to rise in waves, following the leader with a lag. Finally, under the third scenario, net exports should rise substantially in the higher-tech sectors and not so much in lower-tech industries.

In our analysis based on labour productivity, unit labour costs determine competitiveness. From subsection 4.3 we know that East Asia has maintained its strong competitive position in medium-high- and high-tech industries. We concluded that the 'jumping-up approach' is an appropriate catch-up scenario for the East Asian countries and thus expected to find this reflected in the RCAs. Indeed, the RCAs reveal strong improvements in the high-tech industries (even a switchover occurred from a below-average to an above-average position).

The advanced OECD countries gained competitiveness with respect to the US in the low- and medium-tech industries. Competitiveness as revealed by net exports improved primarily in the medium-high-tech industries, which is also the only industry segment

where the initial productivity gap to the US has been closed over the observation period. So, technology catch-up is reflected in relative export market shares.[9]

To summarize, technological convergence and changes in RCAs differ across regions. As we have seen above, in East Asia technological convergence is strongest in the higher-tech industries as opposed to the Northern OECD countries where technological convergence is strongest in the lower-tech industries. This supports our view that different regions are characterized by differences in catching-up processes and competitiveness reflected in the changes of the RCA measure. The empirical evidence presented suggests that the 'jumping-up approach' is more appropriate to characterize East Asia whereas the OECD countries are better described by the 'climbing up the ladder' scenario.

Sectoral differences in productivity in combination with unit labour costs can explain the differences in trade patterns across regions. We conclude that there is a link between technology catch-up and the development of specific trade patterns. Given this link we expect to find significant positive correlations in the whole sample and in each country among the growth rates of productivity, unit labour costs and of imports and exports. The results are surprising. The only country which shows a significant correlation between productivity and trade is the US, where due to its size we would not necessarily expect to find that. Imports in Japan and exports in Indonesia are positively correlated with productivity growth. Besides those two exceptions, no significant correlation could be found in any of the six East Asian countries. It is also interesting to note that exports and imports do not always show a significant correlation in their growth rates. In Hong Kong, high-growth export sectors are in general those with the smallest import growth. In Indonesia and Thailand, the rapidly increasing export industries correspond to those with highest import growth. Thus, this simple correlation analysis does not support the idea of a strong dynamic link between technological catch-up and a certain trade pattern.

However, the development of unit labour costs determines competitiveness, and unit

[9]It has to be kept in mind that unit labour cost convergence is measured with respect to the US only, whereas RCAs are calculated with respect to the sample as a whole. Thus, the pictures drawn by these two concepts are not one-to-one comparable.

labour costs are more often significantly correlated to import and export growth. The link is not between technological progress per se and trade but between technological progress in combination with relative unit labour costs. This supports a dynamic Ricardian view on the subject.

6 Conclusions

In this paper we presented evidence that catching-up patterns are different across countries and industries and do not always follow the patterns implicitly assumed or proposed by the models discussed in section 2. Although these models are interesting in their own right and raise a number of important questions, an empirical look at catching-up patterns at the industrial level reveals that one has to search for models which are more in line with empirically observed patterns of development.

Having stated that technological convergence processes exhibit a diversity across countries and industries, one also has to discuss the implications for the dynamics of trade patterns. This was done in this paper also in an empirical manner at rather high aggregates of industries leaving a more theoretical and detailed study for future research.

In this paper we have not yet explored the mechanisms by which increased productivity translates into increased imports and exports. Several processes can be at work. For instance, building up capacities exceeding domestic demand due to not perfect expectations, industrial policies, etc. leads to excess supply, augments exports and influences trade patterns directly. Further, exports may be driven by demand in foreign countries having capacity problems of their own in some fast growing industries. But we conclude that relative cost advantages seem to be crucial in building a competitive advantage and leading to a strong position in the world market. Thus, emerging countries may start producing goods even in higher-tech industries for the foreign markets without ever having reached the general level of development of the more advanced countries. In this sense, they 'jump up' in specific industries and become net exporters in these industries.

However, the increases in the world export shares of East Asian countries and even

more so of Southern OECD countries may not be fully explained by these underlying economic facts on the production side. Other factors together with the developments in productivity and unit labour costs, omitted in our analysis, must be regarded as being influential in determining trade patterns. For instance, policy measures in both the emerging and the advanced countries are often important parameters in trade issues. In this paper, we have completely abstracted from policy issues, although they are likely to play an important role in most countries and have a significant and large effect on trade volumes. Price competitiveness and high productivity do not necessarily translate into large export shares, as tariffs and international trading agreements (free trade areas - FTAs, preferential trading agreements, but also embargoes) have to be considered as binding constraints. The choice of our sample includes many FTAs (European Union, EFTA, NAFTA, ASEAN) and the like, the effects of which should be explored in further research. Other factors such as foreign direct investment, industrial policies and the education of a skilled labour force, which is a precondition for building up capacities in the more sophisticated sectors, are not discussed here.

A Tables

Country	Name	Group
AUS	Australia	1
AUT	Austria	1
CAN	Canada	1
DNK	Denmark	1
FIN	Finland	1
FRA	France	1
DEW	Germany, Western Part	1
ITA	Italy	1
JPN	Japan	1
NLD	Netherlands	1
NZL	New Zealand	1
NOR	Norway	1
SWE	Sweden	1
GBR	UK	1
USA	USA	1
GRC	Greece	2
ISL	Iceland	2
PRT	Portugal	2
ESP	Spain	2
HKG	Hongkong	3
IDN	Indonesia	3
KOR	Republic of Korea	3
MYS	Malaysia	3
SGP	Singapore	3
THA	Thailand	3

Table A.1: Countries and groupings

Code	Definition	Tech
311	Food products	1
313	Beverages	1
314	Tobacco	1
321	Textiles	1
322	Wearing apparel, except footwear	1
323	Leather products	1
324	Footwear, except rubber or plastic	1
331	Wood products, except furniture	1
332	Furniture, except metal	1
341	Paper and products	1
342	Printing and publishing	1
354	Misc. petroleum and coal products	2
355	Rubber products	2
356	Plastic products	2
361	Pottery, china, earthenware	2
362	Glass and products	2
369	Other non-metallic mineral products	2
371	Iron and steel	2
372	Non-ferrous metals	2
381	Fabricated metal products	2
390	Other manufactured products	2
3841	Ship building and repairing	2
351	Industrial chemicals	3
385	Professional and scientific equipment	3
352d	Other chemicals	3
382d	Machinery, except electrical	3
383d	Machinery, electric	3
384d	Transport equipment	3
3522	Man. of Drugs and Medicine	4
3825	Man. Of Office, Computing and Accounting Machinery	4
3832	Man. of Radio, TV, and Communication equipment and apparatus	4
3845	Man. Of Aircraft	4

Table A.2: Industries and groupings

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