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*Robert Stehrer and
Julia Wörz*

**Industrial Diversity,
Trade Patterns
and Productivity
Convergence**

Robert Stehrer is wiiw research economist and lecturer in economics at Johannes Kepler University. Julia Wörz is wiiw research economist.

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Abstract

Recent developments in economic integration show rather diverse patterns of integration into the world economy. Some countries are remaining in the low-tech industries whereas other countries succeed in becoming competitive also in high-tech industries. In this paper we postulate that positioning oneself at the lower end in the spectrum of high tech industries is more favourable to a country's long term development than aiming at the upper end of low tech industries. We argue that countries which specialise in the lower end of the medium-high tech activities are rewarded by faster productivity increases also in the upper end of the high-tech industries. In contrast, early specialisation in medium-low tech branches yields positive spillovers mainly in the low tech sector, which is not promotive to catching-up in high tech industries. We sketch a theoretical outline of this idea and present econometric results including four aggregate manufacturing branches and 37 countries. In the econometric analysis we also include trade and FDI variables.

JEL-Classification: C22, C23, F14, L6, O14, O33, O41

Keywords: trade and technology, unit root tests, patterns of catching-up

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INDUSTRIAL DIVERSITY, TRADE PATTERNS AND PRODUCTIVITY CONVERGENCE

Robert Stehrer and Julia Wörz¹

1 Introduction

Industry patterns in backward economies in general differ not only in comparison to those of the standard-setting 'advanced' economies, but also among the catching-up countries themselves. Likewise, catching-up processes and paths of economic development vary between different countries. Although specialization in output, trade and also FDI matters crucially for economic development, it is not clear without ambiguity, how a beneficial or growth-promoting industrial structure should look like. Thus, more research at the theoretical and empirical level is necessary to isolate the specific structural features shared by successfully catching-up economies.²

Technology is often considered as being of special importance in this context (see Lucas, 1988, for a benchmark model) and also (Grossman and Helpman, 1991). In this paper we try to establish an empirical link between technology catching-up and trade specialization for a heterogenous set of countries. We use four subsets of industries, i.e. low tech, medium-low tech, medium-high tech, and high tech. Industries are defined at the 3-digit ISIC, rev.2 level, high tech industries at the 4-digit level. Our sample covers 37

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²To complicate the matter further, it is also possible that certain patterns of industrial specialization and structural change promote economic development in some cases and less so in others.

countries, OECD members up to 1994 and selected Asian and Latin American countries, over a time period from 1981 to 1998.

Following the approach suggested by Ben-David (1996) we use unit root tests as a measure of convergence for the four types of industries and for various country groups separately. We then provide statistics which test for unit roots in dynamic panels for all four subsets of industries and various country groups. Finally, we try to explain differences in productivity catching-up between industry segments and country groups by differences in FDI and trade specialization patterns. In other words, we investigate possible determinants of cross-country convergence in productivity levels by focussing on the role of international economic integration.

Section 2 outlines the theoretical idea and summarizes our hypothesis. Section 3 presents data and methods. The next section tests for convergence in a time series setting, using the two different ways described above. Finally in section 5 we estimate a dynamic panel to test for the hypothesized relationships between trade specialization, FDI and productivity growth. This approach allows to include country specific characteristics, e.g. FDI inflows and trade specialization variables which seem to be important in the course of development. Section 6 concludes.

2 Theoretical background

Let us discuss the idea we want to assess empirically in a simple informal way.³ Assume that industries can be classified as low-tech, medium-low tech,

³Redding (1999) analyses the trade-off which a country faces between specialisation according to existing comparative advantages and entering sectors in which this country may have actually a comparative disadvantage in a dynamic Ricardian model with two sectors and endogenously determined technological change (i.e. learning by doing). He concludes that it may be welfare improving for a country to specialise in a sector in which it actually has a comparative disadvantage if this enhances current rates of productivity growth and thus promotes selective policy intervention.

medium-high tech, and high tech. These aggregates themselves consist of various other industries which can be ranked by a measure of technological sophistication (e.g. the productivity level, the growth rate of productivity, R&D expenditures, skill-intensities, etc.). As indicated in figure 2.1 this ranking may imply that some industries in the low tech segment are technologically more sophisticated than in the next group, i.e. the medium-low tech branch. The dashed line in the figure represents competitiveness in the

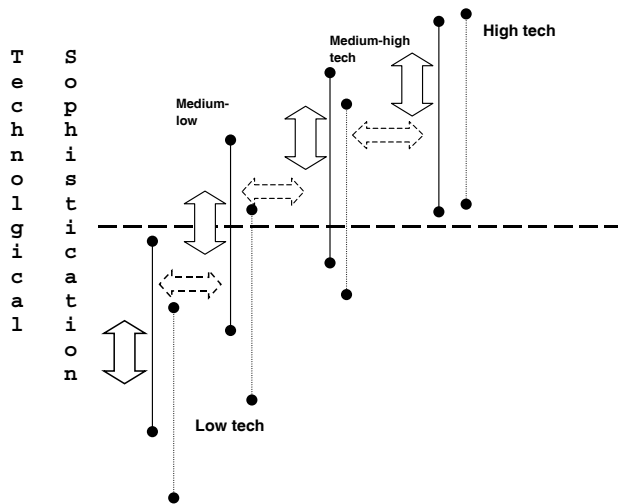


Figure 2.1: Ranking of industries

world markets which we assume to lie on a straight line (we do not discuss the more complicated cases). The line may be determined by the aggregate wage level, exchange rate policies, Porter's comparative advantages of nations, etc. This line may be shifted up- or downwards by e.g. exchange rate policy but for simplicity we assume that the line is fixed.⁴ Below this line a country is competitive, above this line the country cannot compete with

⁴Especially we assume that the line can be shifted only in a narrow range. A developing country may not become competitive in high tech industries by exchange rate policies alone.

other suppliers. Note that the line is drawn in such a way that the country is competitive in all low tech industries, in none of the high tech industries and in the lower branch of the medium tech industries. This would correspond to a moderately developed country like Spain or Thailand for instance.

Traditional trade theory would now suggest that each country specializes in an industry, where it can compete on the world market. This can either be in the low, medium-low or medium-high tech branch.

The longer term position of a country may then depend on the industrial branch in which it specializes initially (or over time). The reason for this is that technology spillovers may occur mainly within one branch as indicated by the vertical arrows. At least they are assumed to be stronger inside one branch. These spillovers can be due to learning processes, intrabrand linkages, etc. A country producing in the lower branch of the food industry may climb up the ladder within this industry faster than jumping to e.g. the electronic industry. On the other hand the East Asian example would mean that a country starts off in the lower segment of the medium-high tech branch (e.g. producing electronic toys) which then allows a country also to start producing e.g. computer hardware components. In this sense industrial learning means that the vertical lines shift downwards as indicated by the dotted lines giving the positions of the branches in a later period.⁵ Learning could also mean that new industries within one branch are establishing which would graphically mean a lengthening of the lines for a particular branch. This assumes that a particular industry is established at the upper end of the e.g. medium-low tech branch even if it is not competitive internationally. As drawn in the figure a country may even lose competitiveness as other countries may gain productivity in this branch. This is indicated in the

⁵For simplicity we assume that the whole line shifts downwards rather than individual industries moving down. Although this is a rather strong assumption this concept generalizes Krugman's notion of a ladder of countries and goods (Krugman, 1994) far enough to allow for country and industry specific catching-up processes and thus gives scope for empirical research.

way that the dotted line in the high tech branch is at a higher position. There can also be spillovers between the branches as indicated by the dashed horizontal arrows. We assume that these spillovers are however weaker than the spillovers within one branch (see the electronic toys-computer hardware example above).

Given the above framework, our argument is the following: A country that specializes in the low-tech branch - even if specialization takes place in the more sophisticated industries of this branch - may get locked-in in the low tech industries. A second country may succeed to posit itself initially in the medium-low tech industries at the remaining lower (less sophisticated) end of this branch where it is competitive. It will then however be able to gain competitiveness in the upper part of this branch as well (i.e. shifting the vertical line downward as indicated by the dotted line). Finally, a third country may aim at the (small) lower end of the medium-high tech branch and may start to climb up the ladder in this branch.

Thus, the driving forces behind the initial positioning of a country are of vital concern, as these will crucially determine a country's long-term prospects. For example, the industrial policy of a country, skill-policies, the creation of industrial clusters, initial conditions, initial trade specialization and the inflow of FDI, etc. all influence economic development.

In this paper we mainly adress the initial conditions, trade specialization and FDI inflows. Given the dataset at hand we test the following empirical hypothesis: In each branch there exists an 'advantage of backwardness' in the Gerschenkronian tradition. A high initial gap will imply a high learning potential leading to faster rates of productivity growth. The same idea was formalized in the recent growth literature under the β -convergence concept (see e.g. Barro and Sala-i-Martin, 1995). This concept was applied at the industrial level in several papers by Landesmann and Stehrer (2000, 2001) and Stehrer and Wörz (2003). However, a large gap in other branches can also be an impediment to productivity growth in a particular branch if there

are strong inter-branch linkages or resource constraints

In the theoretical literature a higher aggregate trade volume is assumed to have a positive effect on productivity growth as it spurs innovation and imitation. We capture this effect by including trade variables into the empirical analysis below. But we have to mention that there can also be a negative effect especially when differentiating across branches. First, a high import share may also mean that a country cannot gain experience in a specific branch and thus never succeeds in catching-up. Further, export specialization in other branches can mean a constraint on resources and thus be an impediment to growth for other industries. Using the figure above, assume that a country is specialized in the medium-low tech branch. This ties up resources in this branch (e.g. skilled workers) which are consequently not available for production in the medium-high tech branch thus preventing a country from a process of 'climbing-up the ladder'. Furthermore, scale-effects are presumably stronger in the low tech and medium-low tech branches, implying a dynamic lock-in in these branches as well.

Finally, there is also a downside to foreign direct investment besides its positive impact on productivity growth. Technological spillovers may take a long time period and again one can argue that the same resource-binding constraints may play a role. According to the industrial allocation of FDI, a high share in one branch may be an impediment for productivity growth in other branches, especially in the case of strong complementary linkages. Given our dataset we can however control only for aggregate effects of FDI inflows.

3 Data and classifications

Comparisons at the industrial level involve a few additional problems to cross-country comparisons at the aggregate level. Besides having to convert the data into comparable units we had to get data for trade and output of

individual industries for a large set of countries at the same level of disaggregation and the same code of classification. The data set covers 37 countries over the time period from 1981 to 1997, subject to availability across countries and industries. Countries are grouped according to geographic region into five distinct classes: OECD North and South, East and South Asia and Latin America (for a listing of countries in each individual group see table A.2 in the appendix).⁶ OECD contains all member countries before 1994 (excluding Iceland), distinguishing between catching-up countries (OECD South, including Greece, Portugal, Spain and Turkey) and advanced countries (OECD North, all remaining member countries).

Time series for manufacturing exports and imports come from the UNIDO Industrial Demand and Supply Database, time series for output, employment, and wages from the UNIDO Industrial Statistics Database. Industries are classified according to ISIC, rev.2, at the 3-digit level, and for particular industries at the 4-digit level. This comprehensive database is unique in covering a large set of countries at this rather disaggregated level. However, sometimes the quality of the data is rather poor, therefore we cross-checked the data for outliers and breaks. As UNIDO reports all series in current US-\$, we used exchange rates from IFS (series rf) to convert all data into national currency units and then expressed them at current Purchasing Power Parities (PPP), using GDP PPP rates from the World Bank.⁷ Data on foreign direct investment (FDI) are not available at this level of disaggregation. Instead we use data on aggregate FDI inflows from the IFS data base.

⁶We started with a larger data set of 43 countries, including Argentina, Bolivia, El Salvador, Nicaragua, Paraguay, and Peru. However, the series for these trade flows were not reliable and added too much noise, so that we did not use them in the analysis.

⁷We are aware of the problems related to the use of aggregate PPP rates (see Sorensen, 2001, for a discussion). Therefore the results have to be interpreted with care as long as appropriate sectoral conversion factors are not available. For a discussion of the issues related to expressing all series in current PPP rates, as is done here, see Landesmann and Stehrer (2000).

The analysis includes 31 industries, excluding oil refining industries. The data set is aggregated with respect to the technology intensity of each industry into four distinct classes (low technology, medium-low technology, medium-high technology, and high-technology intensive), using the classification given in Hatzichronoglou (1997). For a listing of the classification of industries see table A.1 in the appendix.

In the empirical part we use the following variables: Labour productivity LPR_i^c is measured as output per employee, wage rates WAG_i^c are calculated as the wage sum over number of employees and unit labour costs ULC_i^c are LPR_i^c/WAG_i^c . Further we use three different trade variables, each capturing a different aspect of economic integration. The first one is an openness variable given by exports or imports over output, $XSH_i^c = EXP_i^c/OUT_i^c$ or $MSH_i^c = IMP_i^c/OUT_i^c$, respectively. The structure of exports and imports is given by $XSTR_i^c = EXP_i^c/\sum_i EXP_i^c$ and $MSTR_i^c = IMP_i^c/\sum_i IMP_i^c$ respectively. Finally, trade specialization is given by

$$RCA_i^c = \frac{EXP_i^c/EXP_-^c}{EXP_i^-/EXP_-^-} - \frac{IMP_i^c/IMP_-^c}{IMP_i^-/IMP_-^-} = RXA_i^c - RMA_i^c$$

where i denotes industry, c country and $-$ denotes world minus country c and total manufacturing minus industry i , respectively. See Vollrath (1991) for a discussion of this and other trade intensity measures.

4 Convergence in labour productivity

The convergence issue was initially mainly assessed in the cross-section, using the concept of β -convergence and σ -convergence. However, lately time series methods have often been regarded as a more suitable approach since they can be shown to be associated with a stronger notion of convergence (see Bernard and Durlauf, 1995, 1996, on this). Especially the concept of β -convergence used in the aftermath of the work by Barro and Sala-i-Martin (1995) in a number of studies has been criticized for statistical reasons, known

as Galton's fallacy (i.e. regression towards the mean); see especially Quah (1993a,b) and Friedman (1992). Following the critics on cross-section estimates of convergence a number of other approaches have been proposed to test for convergence (σ -convergence, kernel estimation, time series methods). It seems to be acknowledged now that convergence depends to a large extent on the country sample and on the method used. For a discussion on this debate see Evans and Karras (1996), Sala-i-Martin (1996), etc.

We opted for the time series approach in this paper and follow first an approach suggested by Ben-David (1993, 1996) who proposes individual (augmented) Dickey-Fuller unit root tests for each country. The use of unit root tests for individual time series is based on the following consideration: In case of a unit root, the series will follow a random walk, which can be associated with divergence across countries. If, however the presence of a unit root can be rejected in favour of the one sided alternative ($\phi < 1$), the variable (being defined as the gap to the leader) will converge to the level of the leading country. However, unit root tests based on a single time series are known to have limited power against stationary alternatives. Panel unit root tests are seen as a way of increasing the power of individual tests. In a second step we therefore test for unit roots in the panel of countries using a simple method suggested by Maddala (1999) and Maddala and Wu (1999). Similar procedures are suggested by Choi (1999).

We first use the approach suggested by Ben-David (1996) to test for convergence across countries. Taking the criticism of the cross-section approach seriously Ben-David (1996) proposes a simple unit root test for convergence at the aggregate (economy-wide) level of aggregation. In a first step, we use this test to study convergence in productivity at the industrial level for each country and branch separately. Let us denote the gap of the respective variable v of country c in industry i and time t by

$$GAP_{i,t}^c = \ln \frac{v_{i,t}^c}{v_{i,t}^{US}}$$

and use a simple unit root test

$$GAP_{i,t+1}^c = \phi_i^c GAP_{i,t}^c + \varepsilon_{i,t+1}^c$$

Defining $GAP_{i,t+1}^c = \Delta GAP_{i,t+1}^c + GAP_{i,t}^c$ one gets

$$\Delta GAP_{i,t+1}^c = (\phi_i^c - 1)GAP_{i,t}^c + \varepsilon_{i,t+1}^c = \rho_i^c GAP_{i,t}^c + \varepsilon_{i,t+1}^c$$

which is known as Dickey-Fuller test. $\rho_i^c < 0$ means convergence, $\rho_i^c \geq 0$ divergence. The half-life time can easily be computed by $\ln(0.5)/\rho_i^c$ in case of convergence, the double-life time by $\ln(2)/\rho_i^c$. Table 4.1 presents the results for labour productivity for the four industry groups and by country. Due to the small sample size these results have to be interpreted with caution, however they will give us a good indication for convergence.⁸ In this table N denotes the number of observations and H is half-time. According to these individual tests, slightly more than half of the countries in the sample show convergence in productivity to the US-levels (which is the benchmark here). Most of them show convergence in the low and medium technology intensive industries but not in the high technology intensive branches. They are predominantly located in Western Europe and East Asia. Great Britain, South Korea and Singapore are the only three countries which show convergence in the high tech segment. The general conclusion from this is that convergence in productivity mainly takes place in the Northern OECD countries and in the East Asian countries although we cannot conclude that there is a general tendency to converge to the U.S. productivity level. A second point to note is that the half-time for closing the gap is generally lower for convergence in the medium tech and high tech branches than in the low tech branch. Thus, catching-up is faster in these industries compared to low tech industries. The

⁸Reliable conclusions will be drawn in the following section, where panel unit root tests are used. As the individual tests provide us with information about the speed of convergence, which we could not have obtained from the more powerful tests below, we decided to include them here despite this statistical weakness.

Country	Low tech			Medium-low tech			Medium-high tech			High tech		
	ρ_i^c	N	H	ρ_i^c	N	H	ρ_i^c	N	H	ρ_i^c	N	H
AUS	-0.037	11	18	-0.178	11	4	-0.049	11	14	-0.012	11	14
AUT	-0.053	17	13	-0.149	17	4	-0.037	17	4	-0.450	17	17
CAN	-0.058	17		-0.214	17		0.016	17		0.275	17	
DNK	0.029	17		-0.008	17		-0.160	17		-1.154	17	
FIN	-0.066	17		-0.116	17	6	-0.005	17	6	-0.236	17	13
FRA	-0.036	14		-0.095	14	7	0.015	14	7	0.894	14	
GBR	-0.039	17	17	-0.061	17	11	-0.156	17	4	-2.018**	17	4
ITA	-0.276	13		-0.358	13		-0.124	13		-0.906	13	
JPN	0.007	17		-0.148	17		-0.247	17	2	-1.694*	17	2
NLD	0.022	17		-0.174	17	4	-0.564	17	1	-2.603***	17	1
NOR	-0.039	17		-0.124	17	5	-0.003	17	5	-0.055	17	11
NZL	0.025	15		0.042	15		-0.091	15		-0.669	15	
SWE	-0.060	17		-0.113	17	6	-0.032	17	6	-1.061	17	13
ESP	-0.024	17		-0.089	17		-0.155	17	4	-2.071**	17	4
GRC	0.030	17		-0.038	17		0.014	17		0.480	17	
PRT	0.012	16		-0.004	16		-0.061	16		-0.882	16	
TUR	-0.066	17	10	-0.224	17	3	-0.159	17	4	-1.814*	17	4
HKG	-0.041	17	17	-0.108	17	6	-0.077	17	6	-1.488	17	15
IDN	-0.019	15	36	-0.042	15	16	-0.034	16	16	-1.022	16	16
KOR	-0.062	16	11	-0.090	16		-0.091	16	7	-2.399***	16	7
MYS	-0.019	17		-0.037	17		-0.097	17	7	-1.749*	17	7
PHL	-0.020	16		-0.188	16	3	-0.182	16	3	-1.356	16	16
SGP	-0.023	16	30	-0.023	16		-0.041	16		-1.491	16	16
THA	0.030	12		0.009	12		-0.262	12		-1.576	12	
CHL	-0.071	17	9	0.009	17		-0.586	17	1	-2.527***	17	1
COL	-0.262	17		-0.246	17		-0.258	17		-1.315	17	
ECU	-0.036	16		-0.057	16		-0.044	16		-0.831	16	
GTM	-0.061	16		-0.078	16		-0.082	16		-0.757	16	
MEX	-0.001	17		-0.113	17		-0.210	17	3	-1.708*	17	3
PAN	0.017	16		-0.046	16		-0.018	16		-0.213	16	
URY	-0.013	16		-0.011	16		-0.066	16		-0.698	16	
VEN	-0.006	15		-0.070	15		-0.045	15		-0.546	15	
BGD	0.001	11		0.013	11		-0.009	11		-0.473	11	
IND	-0.032	17	21	-0.062	17	11	-0.055	17	11	-1.505	17	14
NPL	0.016	10		-0.020	10			10				
PAK	-0.061	11	11	-0.061	11	11	-0.101	11	6	-1.913*	11	6

Table 4.1: Individual unit root tests

results of this section partly confirm the findings by Landesmann and Stehrer (2001) and Stehrer and Wörz (2003) using the concept of β -convergence.

The findings on individual unit root tests are then used in the panel unit root tests below. The literature on unit root tests in panels was triggered off by the influential work of Levin and Lin (1993a,b). They advocate that the use of panels will result in considerable improvements in statistical power compared to the analysis of single time series. The null hypothesis of a unit root is tested in each individual time series against the alternative that each series is stationary. The simplest model they analyse is

$$\Delta y_{i,t} = \rho y_{i,t-1} + \varepsilon_{i,t} \quad \text{and } H_0 : \rho = 0$$

In contrast to individual unit root tests, the test statistics derived by such models have a limiting normal distribution that depends only on the specification (individual specific intercepts and time trends) and is free from nuisance parameters.

As Maddala and Wu (1999) point out the major limitation of this test is that ρ is assumed to be the same for all units. Thus, the corresponding alternative is $H_1 : \rho < 0$ for all units of observations which is too strong for empirical cases. In our setting this would imply that either all countries in the respective types of industries show a unit root or not. The procedure was generalized by Im et al. (1997). Here, the alternative is relaxed and allows for different ρ_i . This so-called IPS test combines the evidence on the unit root hypothesis from the N unit root tests performed on the N cross-section units. As was again pointed out by Maddala and Wu (1999), this implicitly assumes that T is the same for all units (thus it can only be applied to balanced panel data).

Maddala and Wu (1999) themselves propose a simpler test based on the idea of IPS, i.e. combining the results from N independent tests of a hypothesis. The resulting test is essentially a Fisher test (Fisher, 1932). Using the

p -values of any unit root test one can calculate Fisher's p_λ statistic by

$$p_\lambda = -2 \sum \ln p$$

which follows a χ^2 distribution with $2N$ degrees of freedom (for $T \rightarrow \infty$). The advantages of using this procedure for detecting unit roots in panels - as pointed out by Maddala and Wu (1999) - are first the simplicity of the test, second, that it does not require a balanced panel, third, that it can be carried out for any unit root test derived and, fourth, that various lag lengths may be used. The disadvantage is that the p -values must be derived individually as these do not follow standard distributions in the time series context. Especially the different formulation of the alternative in every single case and the possibility of applying this test to unbalanced panels makes it attractive for the dataset given at hand.

As mentioned above, the main problem is the calculation of the p -values which do not follow a standard distribution. We took the critical values in the Dickey-Fuller tests above to approximate the p -values using the critical values listed in Davidson and MacKinnon (1993).⁹ The values of these statistics are reported in table 4.2 for the sample as a whole, as well as for the five country groups separately. For the total sample the hypothesis of a unit root can be rejected for the low, medium-low and medium-high tech industries. The results for individual country groups reveal however that this overall tendency towards convergence is actually driven by the advanced OECD-countries and

⁹Using the values given in Davidson and MacKinnon (1993), page 708, we approximate the p -values with

$$p = 0.089838\tau_{nc}^2 + 0.4703603\tau_{nc} + 0.6257765$$

for $\tau_{nc} \leq -1.62$ which corresponds to $p = 10\%$ and

$$p = 0.2700617\tau_{nc} + 0.5375$$

for $\tau_{nc} > -1.62$. This means that we used the asymptotic critical values for unit root tests; τ_{nc} denotes the test statistics for the model without a constant or trend. The results presented must thus be seen as a first approximation.

	Low tech	Medium-low	Medium-high	High tech	df
PRODUCTIVITY					
OECD-N	46.65***	62.70***	41.51**	23.79	26
OECD-S	7.28	14.71*	15.19*	10.29	8
East Asia	31.28***	34.12***	32.18***	24.78**	14
Latin America	20.11	21.45	27.37**	10.63	16
South Asia	7.09	16.21**	11.66	3.59	8
Total sample	112.42***	149.19***	127.92***	73.08	72
WAGES					
OECD-N	38.24*	55.20***	37.70*	30.40	26
OECD-S	6.12	9.82	9.94	7.77	8
East Asia	16.22	28.97*	27.23*	26.22*	14
Latin America	7.27	11.79	8.20	6.07	16
South Asia	15.14*	9.78	12.87	3.94	8
Total sample	83.00	115.56***	95.95**	74.40	72
UNIT LABOUR COSTS					
OECD-N	28.04	38.93**	41.74**	27.18	26
OECD-S	9.34	7.93	7.34	7.89	8
East Asia	16.19	15.49	18.13	16.33	14
Latin America	8.86	13.48	17.30	24.14	16
South Asia	9.61	5.91	2.62	3.36	8
Total Sample	72.04	81.74	87.13	78.90	72

Table 4.2: Panel unit root tests

the group of East Asian countries. East Asia is further the only region to show convergence in the high tech industries. Thus, the results from the individual unit root tests are more or less confirmed.

The table also reports results on the unit root tests for wages and unit labour costs. Convergence in wage rates is present only in the medium tech industries. Again, the set of advanced OECD countries and East Asia show converging wage rates with respect to the USA. No significant result was obtained for any other region.

With respect to unit labours costs the sample as a whole never allows to reject the hypothesis of a unit root, thus we do not observe convergence in this important measure of competitiveness. Only the set of advanced OECD members shows converging unit labour costs in the medium tech branches.

5 Technological performance and trade

The reasons for convergence in certain branches are likely to vary across countries. Given the hypothesis that catching-up in one branch may limit the potential for catching-up in another branch, it is important to analyse underlying factors in more detail. In this section we focus on the two aspects addressed in section 2 above: First, do the gaps in other sectors have an influence on convergence? Second, does trade in the same sector as well as in other sectors have an influence on productivity convergence? To tackle these

questions we use the following specification of a dynamic panel model:

$$\begin{aligned}
GAP_{i,t}^c &= \alpha_0 + \sum_g DV^g + \gamma_i GAP_{i,t-1}^c + \sum_{j'}^4 \beta_{1,j'} GAP_{j',t-1}^c + \\
&+ \sum_j^4 \beta_{2,j} XSH_{j,t}^c + \sum_j^4 \beta_{3,j} MSH_{j,t}^c + \beta_4 FDISH_t^c + \varepsilon_{i,t}^c
\end{aligned} \tag{5.1}$$

$$\begin{aligned}
GAP_{i,t}^c &= \alpha_0 + \sum_g DV^g + \gamma_i GAP_{i,t-1}^c + \sum_{j'}^4 \beta_{1,j'} GAP_{j',t-1}^c + \\
&+ \sum_j^4 \beta_{2,j} XSTR_{j,t}^c + \sum_j^4 \beta_{3,j} MSTR_{j,t}^c + \beta_4 FDISH_t^c + \varepsilon_{i,t}^c
\end{aligned} \tag{5.2}$$

$$\begin{aligned}
GAP_{i,t}^c &= \alpha_0 + \sum_g DV^g + \gamma_i GAP_{i,t-1}^c + \sum_{j'}^4 \beta_{1,j'} GAP_{j',t-1}^c + \\
&+ \sum_j^4 \beta_{2,j} RXA_{j,t}^c + \sum_j^4 \beta_{3,j} RMA_{j,t}^c + \beta_4 FDISH_t^c + \varepsilon_{i,t}^c
\end{aligned} \tag{5.3}$$

where g are country groups and j refers to technology intensity of the branch (a dash indicates all branches except branch i). The variables discussed below are expressed in logarithmic terms.

The analysis in this section covers only the subsample of OECD countries and East Asian countries, as for these groups the hypothesis of a unit root was rejected in the preceding section (however not for the high-tech branch). Thus, the dependent variable is stationary. In economic terms, we are now investigating the possible reasons for convergence after having established convergence in section 4. The regressions include dummy variables for the three country groups, OECD North, OECD South and East Asia.

We further account for the effects of foreign capital inflows as these offer a presumably large potential for positive spillovers (knowledge transfer, learning effects, etc.) and their inclusion is thus important in the context of productivity catching-up. Two related aspects of increased (foreign) capital on productivity can be considered: First, given a standard production func-

tion (in the simplest case a Cobb-Douglas production function) more capital increases the marginal and average labour productivity as the capital-labour ratio increases. Second, foreign capital may also increase total factor productivity, i.e. induce technical progress, which in our framework also results in a higher labour productivity measured as output per worker. This latter effect is captured by $FDISH=FDI/GDP$, i.e. we assume that a higher FDI share is positively related to labour productivity growth.¹⁰ The former effect can be captured by aggregate FDI inflows (measured as FDI/POP to account for differences in country sizes). As these two FDI variables are strongly correlated, we use only $FDISH$ in the regressions reported below; similar results are found when using FDI/POP .

The specifications are different with respect to the trade integration variable. In the first specification we included an openness variable (i.e. the share of exports or imports relative to production), the second specification uses instead a measure of export and import structure of the economies and, finally, the third specification uses a measure of revealed comparative advantages which differentiates between exports and imports (see section 3). The specification of a dynamic model, including the lagged dependent variable is similar to the one used in Islam (1995).¹¹ The models have been estimated

¹⁰Unfortunately, sectoral FDI data for the sample at hand were not available to us, so we were restricted to using total FDI (including besides manufacturing the service sector and utilities). We could not investigate the impact of sectoral FDI allocation on productivity, nor could we look at the issue of intra-branch versus inter-branch effects.

¹¹Islam (1995) uses 5-year periods and tries various estimators including a LSDV estimator and a minimum distance estimator. Islam found faster convergence than in typical Barro-regressions. Note however that the coefficient on the lagged dependent variable is assumed to be equal for all countries. This was criticized by Lee et al. (1997) and Im et al. (1997) proposing a heterogenous panel data model. They conclude that if growth rates are equal the Barro-coefficients are biased upwards (slower convergence). In the case that growth rates differ the coefficients from the pooled fixed-effect procedure tend towards one. They suggest a mean group estimator although this may be biased downward in small samples which shows that there are very real difficulties in obtaining precise esti-

with the Arrellano-Bond estimator (see Arrellano and Bond, 1991). We estimated the relationship between international economic integration and productivity catching-up for each branch ($i = 1, \dots, 4$) separately. Results are presented in tables 5.1-5.3. Each column represents a regression on a different dependent variable, namely the productivity gap in the low-tech, medium-low tech, medium-high tech and high-tech industries. The tables also include the Sargan test on over-identifying restrictions and the Arrellano-Bond test on autocovariance of order 1 and 2 in the residuals. The last line shows a χ^2 -test on the hypothesis that the lagged dependent variable equals one. In accordance with the findings of the unit root tests above, this was rejected in all cases - also in the high tech industries - implying convergence.¹²

The coefficient on the gap of the industry under consideration should range between zero and one in order to guarantee a continuous convergence process. The lower the parameter the faster is catching-up for the lagged dependent variable. As one can see the parameter is always positive and significant with the exception of the medium-low tech industry, where it is not significantly different from zero. This would actually imply fast convergence. The 'advantage of backwardness' at the industry level is thus confirmed by our results. Further, the coefficient is highest in the low-tech branch, indicating relatively slow convergence and lowest in the medium-tech branches (i.e. fast convergence). The speed of catching-up in the high-tech sector is in between.

The sign of the parameters for the productivity gap in other sectors has to be positive if a low gap (high productivity level relative to the US) in those sectors is to spur convergence in the respective sector and negative otherwise. A positive coefficient thus indicates spillovers from the other industries to the industry under consideration. A negative coefficient would imply that

mates of the speed of convergence' (Lee et al., 1997). In this paper the primary interest is however not in the speed of convergence but in differences across branches.

¹²No convergence was found for the low tech industries when using alternative trade variables.

Variable	Low tech	Medium-low	Medium-high	High tech
Gap _{1,t-1}	0.753*** <i>0.000</i>	0.323*** <i>0.001</i>	0.082 <i>0.392</i>	-0.014 <i>0.906</i>
Gap _{2,t-1}	-0.007 <i>0.909</i>	0.096 <i>0.242</i>	-0.102 <i>0.144</i>	0.185** <i>0.032</i>
Gap _{3,t-1}	-0.089 <i>0.104</i>	0.012 <i>0.869</i>	0.243** <i>0.001</i>	-0.270*** <i>0.001</i>
Gap _{4,t-1}	-0.022 <i>0.588</i>	0.027 <i>0.627</i>	0.081 <i>0.123</i>	0.539*** <i>0.000</i>
XSH _{1,t}	-0.085*** <i>0.000</i>	-0.008 <i>0.784</i>	0.005 <i>0.873</i>	0.029 <i>0.415</i>
XSH _{2,t}	-0.037* <i>0.066</i>	-0.071*** <i>0.005</i>	-0.039 <i>0.118</i>	-0.003 <i>0.928</i>
XSH _{3,t}	0.001 <i>0.968</i>	0.032 <i>0.194</i>	-0.008 <i>0.738</i>	0.012 <i>0.699</i>
XSH _{4,t}	0.025*** <i>0.004</i>	0.015 <i>0.180</i>	0.035*** <i>0.001</i>	0.028** <i>0.037</i>
MSH _{1,t}	-0.510*** <i>0.000</i>	0.045 <i>0.315</i>	-0.069 <i>0.101</i>	-0.145*** <i>0.007</i>
MSH _{2,t}	0.173*** <i>0.000</i>	-0.184*** <i>0.000</i>	0.196*** <i>0.000</i>	0.195*** <i>0.000</i>
MSH _{3,t}	-0.005 <i>0.913</i>	0.077 <i>0.133</i>	-0.432*** <i>0.000</i>	-0.060 <i>0.340</i>
MSH _{4,t}	0.057** <i>0.027</i>	-0.057* <i>0.084</i>	0.072*** <i>0.018</i>	-0.164*** <i>0.000</i>
FDISH _t	0.013* <i>0.080</i>	0.018* <i>0.055</i>	0.026*** <i>0.005</i>	0.023** <i>0.042</i>
Sargan	0.000	0.006	0.003	0.021
AR(1)	0.000	0.000	0.000	0.000
AR(2)	0.496	0.210	0.746	0.045
Lagged dependent variable = 1	0.005	0.000	0.000	0.000

Table 5.1: Regression results using openness

Variable	Low tech	Medium-low	Medium-high	High tech
Gap _{1,t-1}	0.815*** <i>0.000</i>	0.354*** <i>0.002</i>	0.150 <i>0.238</i>	0.085 <i>0.547</i>
Gap _{2,t-1}	0.133 <i>0.149</i>	0.148* <i>0.098</i>	-0.099 <i>0.251</i>	0.159 <i>0.101</i>
Gap _{3,t-1}	-0.237*** <i>0.007</i>	0.020 <i>0.798</i>	0.314*** <i>0.000</i>	-0.310** <i>0.000</i>
Gap _{4,t-1}	0.022 <i>0.727</i>	-0.011 <i>0.854</i>	0.097 <i>0.119</i>	0.617*** <i>0.000</i>
XSTR _{1,t}	-0.039 <i>0.612</i>	0.107 <i>0.141</i>	-0.029 <i>0.702</i>	0.138 <i>0.122</i>
XSTR _{2,t}	-0.045 <i>0.240</i>	0.045 <i>0.180</i>	-0.103*** <i>0.004</i>	-0.010 <i>0.795</i>
XSTR _{3,t}	0.004 <i>0.923</i>	0.042 <i>0.259</i>	0.028 <i>0.473</i>	0.057 <i>0.206</i>
XSTR _{4,t}	-0.010 <i>0.699</i>	0.032 <i>0.219</i>	0.022 <i>0.419</i>	0.065 <i>0.038</i>
MSTR _{1,t}	-0.029 <i>0.838</i>	-0.080 <i>0.492</i>	0.041 <i>0.753</i>	-0.076 <i>0.593</i>
MSTR _{2,t}	0.003 <i>0.985</i>	0.086 <i>0.509</i>	0.134* <i>0.329</i>	0.067 <i>0.667</i>
MSTR _{3,t}	0.100 <i>0.723</i>	-0.108 <i>0.662</i>	0.016 <i>0.952</i>	-0.058 <i>0.843</i>
MSTR _{4,t}	0.109 <i>0.401</i>	-0.072 <i>0.526</i>	0.014 <i>0.910</i>	-0.075 <i>0.578</i>
FDISH _t	0.018 <i>0.129</i>	0.015 <i>0.158</i>	0.024** <i>0.035</i>	0.024* <i>0.057</i>
Sargan	0.000	0.014	0.002	0.080
AR(1)	0.001	0.000	0.000	0.000
AR(2)	0.581	0.727	0.402	0.253
Lagged dependent variable = 1	0.173	0.000	0.000	0.000

Table 5.2: Regression results using trade structure

Variable	Low tech	Medium-low	Medium-high	High tech
Gap _{1,t-1}	0.843*** <i>0.000</i>	0.349*** <i>0.003</i>	0.157 <i>0.224</i>	0.096 <i>0.504</i>
Gap _{2,t-1}	0.132 <i>0.154</i>	0.141 <i>0.118</i>	-0.099 <i>0.249</i>	0.162* <i>0.098</i>
Gap _{3,t-1}	-0.218** <i>0.012</i>	0.003 <i>0.971</i>	0.297*** <i>0.001</i>	-0.310*** <i>0.000</i>
Gap _{4,t-1}	0.006 <i>0.930</i>	0.006 <i>0.923</i>	0.111* <i>0.078</i>	0.620*** <i>0.000</i>
RXA _{1,t}	-0.021 <i>0.722</i>	0.078 <i>0.160</i>	-0.048 <i>0.405</i>	0.135* <i>0.053</i>
RXA _{2,t}	-0.037 <i>0.406</i>	0.051 <i>0.182</i>	-0.102 <i>0.012</i>	0.039 <i>0.404</i>
RXA _{3,t}	0.002 <i>0.961</i>	0.052 <i>0.191</i>	0.011 <i>0.799</i>	0.085* <i>0.082</i>
RXA _{4,t}	-0.005 <i>0.880</i>	0.036 <i>0.210</i>	0.003 <i>0.923</i>	0.084** <i>0.020</i>
RMA _{1,t}	-0.133 <i>0.367</i>	-0.075 <i>0.542</i>	0.056* <i>0.674</i>	-0.173 <i>0.248</i>
RMA _{2,t}	-0.059 <i>0.710</i>	-0.030 <i>0.826</i>	0.142** <i>0.325</i>	-0.042 <i>0.798</i>
RMA _{3,t}	-0.067 <i>0.755</i>	-0.097 <i>0.610</i>	0.116 <i>0.562</i>	-0.206 <i>0.361</i>
RMA _{4,t}	0.030 <i>0.832</i>	-0.089 <i>0.470</i>	0.092 <i>0.480</i>	-0.124 <i>0.401</i>
FDISH	0.019 <i>0.103</i>	0.016 <i>0.135</i>	0.024** <i>0.030</i>	0.026** <i>0.040</i>
Sargan	0.000	0.011	0.003	0.107
AR(1)	0.001	0.000	0.000	0.000
AR(2)	0.419	0.596	0.483	0.315
Lagged dependent variable = 1	0.264	0.000	0.000	0.000

Table 5.3: Regression results using revealed comparative advantages

productivity convergence in the respective industry group is slowed down or even impeded because of the closure of the productivity gap in the other sector. A reason for this could be lack of resources (e.g. on skilled labour) to catch-up in the other sector as well.

Looking first at table 5.1 we see that significant cross-industry coefficients can only be found in the upper triangle implying that catching-up in the respective less technology intensive sectors is beneficial for the more technology intensive sectors. Overall, lower productivity gaps in less technology intensive industries foster catching-up in the higher tech branches, which is indicated by the significantly positive coefficients in the upper triangle of the gap variables in tables 5.1-5.3. However, we find a significant negative spillover from the medium-high to the high tech sector which may be explained by resource binding as mentioned above. These medium-high tech industries are also the ones where convergence is most rapid. These results are rather robust to the inclusion of the other trade variables (see tables 5.2 and 5.3). In the latter two specifications we see, however, a negative spillover from the medium-high tech industry to the low tech industry.

These results suggest the following argument: On the one hand, catching-up in less technology intensive branches has positive spillovers to the higher tech branches and thus catching-up progresses stepwise across branches (i.e. countries are climbing up the ladder). On the other hand, the negative spillovers from medium-high tech industries to the high tech (and in one case to the low tech industries) implies that catching-up in higher tech branches reduces the scope for convergence in other branches. Empirical studies (e.g. Stehrer and Wörz, 2003) show that the first pattern can be found for the less developed European OECD countries, whereas the second type of catching-up is relevant for the East Asian countries.

For the coefficients of the trade variables we expect a positive sign which implies that a high degree of openness (a high relative share of the industry in total exports or a strong revealed comparative advantage respectively

in the other two specifications) promotes convergence for the industry segment under consideration. A negative coefficient implies a negative effect for productivity catching-up.

Let us first discuss the results we obtain when using the openness variable (table 5.1). In the lower tech branches we find a negative coefficient which implies that convergence is slowed down. This result can either be interpreted as a lock-in in a certain kind of technologies; i.e. promoting industrial convergence in the medium-high tech industries with negative spillovers in the lower tech branches as we have seen above and opening trade in all branches at similar rates implies that these countries are less competitive in the lower tech branches. This implies a shift in the structure of comparative advantages over time. On the other hand, in the high tech branches we find a significant positive coefficient; openness leads to higher productivity growth. There are further positive effects of openness from this sector to the low-tech and medium-low tech sectors.

Imports have in all branches a negative effect on productivity convergence which can be interpreted as a limited scope for learning-by-doing. A high technology gap implies a higher import share; this result is in line with the finding by Stehrer and Würz (2003), that changes in the revealed comparative advantages were mainly due to changes in the export structure. On the other hand, there are positive spillovers to other industries in some cases. Remarkably are the positive effects on the high tech industries and from the medium-low and high tech industries. Especially the latter can be interpreted with the positive spillovers from trade embodied knowledge and other intangibles.

Finally, the effect of the FDI measures is positive for all branches and relatively higher (and more significant) in the higher tech branches. The latter is confirmed using the other trade variables where the variable is only significant for the medium-high and high tech industries.

The conclusions concerning the 'advantage of backwardness' and the in-

fluence of FDI are robust to the use of alternative trade measures (trade structure and revealed comparative advantages). Also, the evidence for productivity enhancing spillovers from other branches remain more or less the same.

However, the coefficients on the trade measures themselves vary considerably across different specifications. If the composition of trade (i.e. trade structure) or revealed comparative advantages are used instead of openness, nearly all of the trade-related effects disappear. Only some of the spillover effects remain significant.

The trade structure practically does not explain productivity convergence at all, there are neither significant intra-branch effects nor any significant cross effects, except for the negative sign on medium-low tech exports in the regression for medium-high tech industries (and a positive sign for imports). Results for the trade specialization variable are not very different. There are again no effects from specialization in one industry on the performance of the same industry except for the positive intra-branch effect of specialisation in high tech industries. Spillovers from specialization in other industries are only present in the medium-high and high tech sector.

6 Concluding remarks

The paper sketched a framework for looking at the dynamics of sectoral productivity convergence and implications of specialization patterns on sectoral productivity growth. We distinguished four branches (low tech, medium-low tech, medium-high tech, and high-tech) and assumed that it is easier for a country to climb up the ladder within one branch than to jump to other branches. This means that initial (trade) specialization in one of the branches may have a longer-term effect on a country's position in its international performance (see also Redding (1999)). Further we discussed potential negative spillover effects across branches in the case of trade specialization patterns

and studied the differential effect of FDI in the respective branches.

We estimated a dynamic panel framework and tested for convergence. The above stated hypotheses have been confirmed *grosso modo*. We found convergence (by using individual unit root tests and in the dynamic panel framework) in sectoral productivity levels, with the exception of the high-tech industries. The structural regression model in section 5 confirmed the existence of an 'advantage of backwardness' at the branch level, while at the same time the closure of the gaps in relatively lower tech branches turned out to stimulate productivity growth in the more technology intensive branches. In general, intra-branch spillovers were nearly always significant while fewer inter-branch effects were found. Thus, the first hypothesis was more or less confirmed while the positive influence of trade (and especially of trade specialization) was less confirmed. The impact of the trade variables was only significant, when openness at the industrial level was used.

Openness on the export side enhanced convergence only in technology intensive industries. Significant negative effects on productivity were found in lower tech activities. A high import penetration inside the same industry segment yielded a negative impact on productivity catching-up. There were, however, positive spillovers from imports in medium-low and high tech industries. Trade structure and trade specialization never had a significant impact on productivity convergence. Besides these direct effects, only very few trade related inter-industry effects were found.

Finally, FDI has a productivity enhancing effect in all branches. This effect seems to be stronger in the higher tech activities relative to the lower tech branches. Further research should also look at the allocation of FDI, which would allow to indentify spillovers from FDI inflows inside and across industries.

Given the empirical evidence from our paper, we would conclude - in line with Redding (1999) - that selective policy measures (i.e. export subsidies, specific training of the labour force while constraining imports in order to

protect infant industries) can be welfare improving under certain conditions. Given that a country has a dynamic comparative advantage in a specific industry - in the sense that while a current comparative advantage is lacking, temporary trade and industrial policies induce the endogenous development of a future comparative advantage in this industry - specialisation against initial comparative advantages may be optimal. Less developed countries typically hold their static comparative advantages in resource and labour intensive industries with little technology content. According to new growth theories this will put limitations on their long-run growth potential. Consequently, these countries may realise a large growth potential when they succeed in identifying those industries that will offer them dynamic comparative advantages. Policy induced specialisation in these industries, even when coupled with temporary protectionist measures, will prove optimal from a long-term welfare point of view. The East Asian countries, whose governments have pursued exactly such a strategy up to the beginning of the 1980s - by educating the labour force while keeping domestic markets initially rather closed and following a policy of careful and stepwise opening up - are a prominent example of such a development trajectory. The empirical evidence presented in our paper underlines the possibility that static and dynamic comparative advantages may fall apart with important consequences for a country's long-term development path.

A Tables

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
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.1: Industries and groupings

Country	Name	Group
AUS	Australia	1
AUT	Austria	1
CAN	Canada	1
DNK	Denmark	1
FIN	Finland	1
FRA	France	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
PRT	Portugal	2
ESP	Spain	2
TUR	Turkey	2
HKG	Hongkong	3
IDN	Indonesia	3
KOR	Republic of Korea	3
MYS	Malaysia	3
PHL	Philippines	3
SGP	Singapore	3
THA	Thailand	3
CHL	Chile	4
COL	Columbia	4
ECU	Ecuador	4
GTM	Guatemala	4
MEX	Mexico	4
PAN	Panama	4
URY	Uruguay	4
VEN	Venezuela	4
BGD	Bangladesh	5
IND	India	5
NPL	Nepal	5
PAK	Pakistan	5

Table A.2: Countries and groupings

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