11 Competing for Growth: The Dynamics of Technology Gaps*

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1 INTRODUCTION

In this paper we elaborate, on the basis of previous research (see, in particular, Dosi, Pavitt and Soete, 1990; Soete and Verspagen, 1993; and Verspagen, 1992a), on the relationship between technological change and growth within an open economy framework. Despite the increasing popularity of this topic in much recent theoretical research in the so-called 'new' growth and trade tradition (see, in particular, Grossman and Helpman, 1991), the paper does not attempt to add to this rapidly growing literature. Instead, it more modestly aims at presenting some evidence and a number of empirical tests which might help in focusing the discussion on some major policy issues of long-term development, trade specialization and technology. We hope that the empirical analysis presented here is of a sufficiently wide and general nature as to provide linkages with the new growth and trade framework, as well as the Schumpeterian or evolutionary tradition (see, among others, the contribution of Dosi and Freeman in this volume).

On the paper distributed at the conference, we had originally added a sub-title: 'Condvergence and Innovation'. This somewhat ludic subtitle, apart from representing our particular contribution to the recent economic policy tradition of coming up with new, contradictory punchwords (glocalization, competeration, prosumer, etc.), highlights a number of more serious features of long-term development and technological change which will be at the core of our paper. First, the international process of long-term development can historically probably be best understood as a continuation of periods of convergence and divergence in economic growth of particular economies. Second, such processes can indeed be closely linked with the two features of technological change, associated with innovation and imitation and
encapsulated in our punch word ‘imovation’ (or for those who have other preferences in the bastardization of the English language, ‘innomation’), i.e., the generation of new ideas and the acquisition and imitation by others of such new ideas. As a parenthetical, it is worthwhile emphasizing that these latter features of technological change are also at the core of much ‘new’ growth thinking (see, in particular, Romer’s 1992 recent discussion on ‘ideas’).

Sections 2 and 3 of the paper deal primarily with the importance of technological advantages, both for growth and for trade specialization. Section 2 presents some aggregate data on long-run growth, and summarizes some evidence on the determinants of postwar catching-up growth and trade performance in the OECD area. Section 3 briefly summarizes – in a non-formal way – the sectoral theoretical ‘vision’ behind the empirical analyses in sections 4 and 5. This vision is based on a more formal theoretical framework developed elsewhere (Dosi and Soete, 1983; Cimoli and Soete, 1992; and Verspagen, 1992a), and, given space constraints, not reproduced here. The ‘core’ of our analysis is then represented in sections 4 and 5. In section 4, the emphasis is on the differences between countries in innovative capacity (so-called technology gaps) and the explanation that such differences might provide for sectoral specialization. Section 5 deals more explicitly with catching-up, technology diffusion and imitation. The empirical analysis brings to the forefront some features which can reasonably be associated with technological catching-up processes and imitation. In conclusion, in section 6, we draw some policy conclusions which go some way in re-emphasizing the importance of international access to technology for long-term development.

2 THE DYNAMICS OF LONG-RUN GROWTH

Most of the literature in the field of long-run economic development, international technology diffusion and technological ‘catching up’ can be seen as a straightforward application of the so-called epidemic diffusion model found in the literature on technological change.¹ The basic conclusion that arises from this early strand of development literature is that technologically backward countries are in a relatively advantageous position, because they can assimilate at low costs technology spill-overs (imitation), and converge to the per capita income level corresponding to the technological frontier rapidly.

The ‘automatic’ way in which such international diffusion of
knowledge was assumed to take place has been criticized in many studies based on more in-depth historical research on the emergence of technological and economic leadership and processes of catching up and taking over, on the use and adoption of particular technologies. More recently, some 'convergence' between these two strands of literature seems to be taking place. As highlighted by Abramovitz (1992), this convergence puts the emphasis clearly back on the historical institutional framework within which such processes of imitation/technological catching-up take place, including the role of historical accidents, the importance of 'developmental' constraints — be they primarily economic (such as the lack of natural resources) or more political in nature — the role of immigration (see Scoville, 1951) and other 'germ carriers', and the crucial role of governments (see Yakushiji, 1986).

In another publication, one of us developed and tested a model taking into account some of these considerations (Verspagen, 1991). The model stressed the importance of the concepts of technological distance and the capability to assimilate knowledge spill-overs in the development process. Its nonlinear specification led to a bifurcation scheme, in which countries lagging too far behind the frontier, and lacking enough assimilation capabilities, would fall further behind rather than catch up. Despite the simple nature of the model, the specification was rich enough to encompass both 'automatic' catching-up (as a special case), and a 'probit'-like development pattern. Empirical tests of the model showed that among the factors contributing to the assimilation capability education of the labour force was a most prominent one (see also Baumol et al., 1989 on this matter).

The empirical test of this model showed, however, that within the set of 'rich' OECD countries, the simple idea of catching-up seems to make sense, even without the qualifications mentioned above. As some of the quantitative, historical analyses of economic growth and development have illustrated (see, among others, Abramovitz, 1992; Maddison, 1991), particular periods in history can indeed be associated with overall tendencies of convergence as opposed to divergence in economic growth.

In order to highlight some of the peculiarities of the catching-up phenomenon, we present in Figure 11.1 the long-term trend, which puts any particular convergence tendency in its historical perspective. The dotted line gives the average percentual distance from the frontier value of per capita GDP for the 16 OECD countries (as in Maddison, 1991) over the twentieth century. Denoting per capita GDP by $Y$, using subscripts $i$ and $t$ for countries and time (respectively), and a superscript $f$ for the maximum value in the sample, the indicator is
defined as $\ln n \sum (Y_i^f - Y_b)/Y_b$. A downward (upward) trend in the figure indicates convergence (divergence) to the frontier value $Y_i^f$.

Thus, it can be seen that before the Second World War there were no strong convergence or divergence tendencies (except perhaps for the Great Depression period). That war of course created huge per capita income disparities, with the leading country (USA) not being affected by the mass destruction of its production means, as were many European countries and Japan. The postwar period was characterized by a strong convergence trend, bringing income disparities below the pre-1930 levels. Recently (since the late 1970s), the convergence trend seems to have come to an end.

The convergence idea can be illustrated by some simple cross-country regressions, relating the growth rate of per capita GDP to its initial level, expecting a significantly negative coefficient in case of convergence. Besides the initial level of GDP per capita, a long list of variables has been suggested as ‘controlling’ variables (see, for example, the contribution by Levine and Zervos in this volume). Along these lines, we present regressions using the following variables:

$G$: average annual growth of per capita GDP over 1963–85
Table 11.1  Regressions explaining $G$ (n = 20)

<table>
<thead>
<tr>
<th>Eq #</th>
<th>$L_{1963}$</th>
<th>$K_{1963}$</th>
<th>$K_{1970}$</th>
<th>$R_{1970}$</th>
<th>$c$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.006</td>
<td>0.004</td>
<td>0.59</td>
<td>0.05</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5.46***</td>
<td>(2.09**)</td>
<td>(2.80**)</td>
<td>(16.47***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.005</td>
<td>0.002</td>
<td>0.510</td>
<td>0.048</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.86***</td>
<td>(1.94*)</td>
<td>(2.05*)</td>
<td>(11.68***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$K$: the ratio of gross investment to employment, for some specified year

$L$: level of per capita income, in PPP US$ 1985, for some specified year

$R$: R&D as a percentage of GDP, for some specified year.

The regressions are carried out for a set of twenty OECD countries. Values between brackets are absolute $t$-values. In general, (slight) variations in the periodization of one variable does not change the results.

These two regressions of Table 11.1 illustrate the general finding that growth rates of per capita income are inversely related to the latter's initial level. Moreover, the significantly positive coefficients for the investment and R&D variables show that differences in the level of these variables induce growth rate differentials. Thus, while the influence of imitation brings about a converging tendency, there are also (possibly) diverging tendencies present in the form of investment in fixed capital and technology as well as some other variables that are not in our regressions.

The role of trade in the debate on long-run growth and catching-up has generally been limited to its function as a 'carrier' of technological knowledge, as embodied in intermediates and capital goods (see, for example, Hellariell and Chung, 1991; and Hellariell's contribution in this volume). While sympathetic towards this idea, we feel that the role of trade in the catching-up process might be broader.

One question related to trade and catching-up that comes to mind, is whether or not convergence has taken place in the field of international trade. While section 5 is devoted to an in-depth sectoral analysis investigating this question, we present here some preliminary empirical results, giving a first idea of the answer to this question. We estimate the same sort of catching-up relations as in Table 11.1, this time, however, with trade performance as the dependent variable. Furthermore, we estimate an equation to find out whether there exists a rela-
Table 11.2  Catching-up in the trade field (dependent variable E, n = 20)

<table>
<thead>
<tr>
<th>Eq #</th>
<th>$L_{1970}$</th>
<th>$K_{1980}$</th>
<th>$B_{1970}$</th>
<th>$G$</th>
<th>$c$</th>
<th>$R^2$</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.004</td>
<td>0.008</td>
<td>-0.021</td>
<td>-0.008</td>
<td>(0.47)</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>(2.70**)</td>
<td>(2.70**)</td>
<td>(1.80*)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.005</td>
<td>0.006</td>
<td></td>
<td>0.015</td>
<td>(1.13)</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>(4.04***)</td>
<td>(2.19**)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>13.262</td>
<td>-0.295</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.29**)</td>
<td>(1.66)</td>
<td></td>
</tr>
</tbody>
</table>

Relation between catching-up in a growth sense, and trade performance. To do this, two additional variables are introduced, which are defined as follows:

- **B**: Trade balance, defined as the natural log of the export–import ratio, for some specified year
- **E**: Average annual growth rate of the export market share for manufacturing products over 1970–85

We estimate equations explaining $E$ by means of the initial values of $L$ and $B$, as well as the value for $K$ in 1980, and $G$. The results for these estimations are documented in Table 11.2.

The regressions indicate that there seems to be a strong catching-up relation in the field of international trade too. Both the level of per capita income and the initial trade balance are inversely related to the evolution of trade performance of the subsequent period, while investment is (again) positively related to performance. R&D intensity did not yield significant coefficient estimates. Moreover, there is also a clear relation between catching up in a growth sense and (dynamic) trade performance (equation 3 in the table), which is to some extent not surprising given the fact that exports are part of national income.\(^5\)

Questions that emerge from this analysis are: What is the relation between trade and growth, and what is the exact role of trade in the catching-up process? Does it play a role in facilitating absorption of foreign knowledge? Or does it reinforce structural differences between countries, leading to diverging growth? Or is there perhaps an imitation tendency in world markets, leading to convergence in trade and specialization? This is what the rest of this paper will investigate. The next section sketches a theoretical base, used to interpret the empirical results in the last two sections.
3 TECHNOLOGICAL GAPS, GROWTH AND INTERNATIONAL SPECIALIZATION: A SIMPLE THEORETICAL FRAMEWORK

Neoclassical growth theory has been criticized for its representation of technological change as an exogenous trend by many scholars outside mainstream theory (see, for example, Nelson, 1981; Nelson and Winter, 1982), long before 'new' growth theory brought the issue of endogenous technological progress into mainstream thinking. One of us having contributed for some time to this criticism from a more 'structural' Schumpeterian perspective (see, among others, Freeman, Clark and Soete, 1982; Freeman and Soete, 1987), we base our analysis on this latter line of thinking, even though most of the ideas put forward are consistent with many new growth and trade theory contributions.

Our difference in emphasis can be summarized under the following three assertions which shape our interpretation of the complex sets of interactions between growth, technological capabilities and specialization. First, the short-run growth possibilities of an economy are limited by the country's technological 'capabilities'. Technology is not a free good, but shows varying degrees of appropriability at the company and country level, an assumption that is now shared by the Schumpeterian and neoclassical traditions. In the short run, this means a technological lead relative to competitors will enable a country to grow faster and 'diverge', while in the longer run there are opportunities for laggards to catch up.

Second, the domestic pattern of production of a country does not depend solely on the nature of its domestic consumption and production coefficients, but also on factors shaping international specialization and international terms of trade. We argue in line with Pasinetti (1981) that income elasticities and the production structure of a country therefore are crucial factors determining growth.

Third, imports have in the final instance to be paid by the country's exports, which means that not only the absolute technological levels of each economy determine the maximum attainable per capita income and rate of accumulation, but also the relative technological levels between countries. This affects the growth possibilities of each economy via the balance of payment constraint.

In order to see how this emerging specialization pattern affects differences in growth rates among countries, simple ('Keynesian') national accounting identities suffice. The open economy income multiplier is smaller than the closed economy income multiplier, because
of import leakage effects. Whether through the reallocation of resources and the resulting effect on relative prices, or through more macroeconomic Keynesian open economy income multiplier effects, larger exports will positively influence national income. Thus, if we endogenize both export and import performance by means of introducing technology in the analysis, international trade is an important determinant of growth patterns: a conclusion which is much in line with open new growth models (Grossman and Helpman, 1991).

An important question that arises in this context is how the openness of the economy affects countries. Standard trade theory argues that all countries benefit from trade. However, interpreting the relation between trade and growth using the macroeconomic income accounting identity, 'Pareto efficient' trade is no longer obvious.

The suggested framework for assessing the relation between trade and growth basically argues for two effects: first, the volume of exports has a positive effect on national income (growth), and second, there is a negative effect of increased import penetration on domestic income, through a smaller value of the multiplier. Combined, these two effects lead to the well-known prisoner's dilemma: while it is beneficial to all individual countries to increase their exports and discourage imports, the sum of these individual behaviour patterns leads to an inefficient aggregate outcome. The 'logic' behind 'early' mercantilism can be interpreted as playing this prisoner's dilemma game in an unrepeated context, yielding the least efficient outcome. In purely mercantilistic terms, a country which cannot increase its exports to the extent of offsetting the effect of an increasing import penetration, is worse off in the long run. On the other hand, a country whose increased exports outweigh the increasing import penetration (or even better, add to the effect of decreasing import penetration) is better off in the long run. In terms of the trade balance, a surplus is a facilitator for economic growth, a deficit a brake.

This extreme mercantilistic point of view will of course not be defended here. A 'structuralist' view might be more revealing. The sectoral distribution of production at the global level is determined by the sectoral distribution of consumption patterns. Due to specialization, however, consumption and production patterns may differ at the national level. If countries (ultimately) face a balance of payments constraint to growth (see, among others, Thirlwall, 1979; Fagerberg, 1988), the structure of demand in the domestic and foreign economies determines whether or not a country will grow faster than the world
average. Along the lines of Pasinetti (1981), the assumption of differences in income elasticities and/or differences in income levels will then quite naturally induce growth rate differentials.

The sequence of this line of argumentation is illustrated in Figure 11.2. Starting with the influence of technological competitiveness on trade performance and specialization, one may first note the role of income elasticities in determining the demand potential domestic producers face.

This covers the part of the cycle in Figure 11.2 that leads from technological performance, via exports, to economic growth. Although the demand-related effects in our approach are usually considered to be relevant only in the short run, the argument is also relevant to the longer run. The reason for this is that in the remaining part of the cycle in Figure 11.2, economic performance feeds back on competitiveness.

First, there is a strong case to be made for positive feedbacks between technological capabilities and economic performance. Drawing upon some arguments with regard to the nature of technological change as a search activity, the outcomes of which are highly dependent on decisions made in the past under circumstances of strong uncertainty (not just imperfect foresight – see Dosi, 1988), we argue that strong economic performance in some fields has a positive influence on the exploitation of future technological possibilities in the same field. In the literature, this has often been interpreted as 'learning' of various
types, as in the analysis of productivity growth by, among others, Kaldor (1957) and Dixon and Thirlwall (1975).

Looking at technological competitiveness this way leads to a strong presumption of the existence of cumulative processes, which can give rise to a large variety of possible growth paths, for example, slow take-offs followed by rapid growth, and eventually slowdowns due to falling payoffs, or lock-in no-growth traps. The reason why these growth paths will in many cases be by and large consistent with an employment path fluctuating around some "normal" level, lies in the feedback from growth performance to competitiveness arising from the flexibility of wages and exchange rates. Badly performing economies can adjust these two variables, in order to become more competitive again, while strongly performing economies will be forced to do so, due to (short-run) capacity limits.

What becomes clear from this analysis is that it leads quite naturally to international divergence in growth, rather than convergence in growth paths. The reason for this can be found in the way differences in technological capabilities, which induce growth rate differentials, have been stressed. No variables producing a negative technological feedback, i.e., which have the property that low initial levels of performance lead to high growth in the subsequent period, have been introduced. This second type of feedback, of which imitation is the prime example, will be the main concern of section 5 below. The fact that it is likely to express itself only in a somewhat longer run, might be a reason why it has received much less attention in empirical analyses of trade.

Imitation of technological knowledge enables lagging countries to catch up to the technological frontier, either by small step imitation of foreign technology or technological 'leapfrogging' (Soete, 1985). Thus, while the above-mentioned positive feedbacks will induce uneven growth, imitation will exert a converging tendency. The interplay of these two trends, in a context without a strong equilibrium tendency such as rational technological expectations, will lead to dynamics which are much more complicated than just steady state growth or transitory dynamics towards it (see the contribution of Dosi and Freeman in this volume, as well as Verspagen, 1992a). In these complex dynamics, Maddison's (1982) idea of phases of growth seems much more relevant than the stylized facts that underlie most 'mainstream' theory.7

This is what we have in mind when we speak of the complex dynamics of condvergence and innovation. And while we feel that reality
does in general not display a sharp distinction between imitation and innovation, or convergence–divergence, we will still maintain the analytical difference in the two following sections. The concluding summary in section 6 will than bring the two forces together.

4 TESTING THE STRUCTURAL IMPACT OF TECHNOLOGY ON TRADE

The aim of this section is to provide some tests for the basic ideas on the structural relation between trade and technology presented in the above section.

Let us start with a somewhat unconventional test in which we relate the degree of competition in a sector to its technological intensity. The latter is measured by the (weighted) average of R&D intensity in the US, Japan and Germany. R&D intensity is defined as the sum of R&D expenditures in the three countries as a percentage of the sum of value added, and is denoted by $R$. The degree of competition, denoted by $C$, is measured by an entropy coefficient, defined as $\Sigma x_i \ln(1/x_i)$, with $x_i$ denoting the share of country $i$ in total (OECD) exports.

The regression is carried out for a 1988 cross-section sample of 21 sectors documented in Table 11.3, and gives the following results (figures between brackets are absolute $t$-statistics):

$$C = -0.021 \ (7.35) \ R + 2.529 \ (69.6) \ \text{adj.} \ R^2 = 0.73.$$  

The regression, which gives the same outcomes for different years, illustrates the role of monopoly power in internalizing the payoffs to innovation efforts, much in line with early ideas in the Schumpeterian tradition, as well as the new growth models. The fact that these monopolistic market structures do not wear off immediately points to the role of technology as a barrier to entry in the high-tech sectors. In fact, the (statistical) role of R&D intensity in this respect is much stronger than that of more traditional variables related to barriers of entry. Similar regressions carried out with investment intensities as the independent variable yielded non-significant results.

The relevance of this regression to the analysis in the previous section is obvious. The results support the notion of technological competitiveness as an important determinant of trade (and thereby growth).
### Table 11.3 Manufacturing sectors used in the regressions

<table>
<thead>
<tr>
<th>Number</th>
<th>ISIC-2 code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3100</td>
<td>Food, beverages and tobacco</td>
</tr>
<tr>
<td>2</td>
<td>3200</td>
<td>Textiles, apparel and leather</td>
</tr>
<tr>
<td>3</td>
<td>3300</td>
<td>Wood and wooden furniture</td>
</tr>
<tr>
<td>4</td>
<td>3400</td>
<td>Paper and printing</td>
</tr>
<tr>
<td>5</td>
<td>3522</td>
<td>Drugs and medicines (pharmaceuticals)</td>
</tr>
<tr>
<td>6</td>
<td>3510, 3520, ex. 3522</td>
<td>Other chemicals</td>
</tr>
<tr>
<td>7</td>
<td>3530, 3540</td>
<td>Refined oil, oil and coal products</td>
</tr>
<tr>
<td>8</td>
<td>3550, 3560</td>
<td>Rubber and plastic products</td>
</tr>
<tr>
<td>9</td>
<td>3600</td>
<td>Non-metallic mineral products</td>
</tr>
<tr>
<td>10</td>
<td>3710</td>
<td>Ferrous metals</td>
</tr>
<tr>
<td>11</td>
<td>3720</td>
<td>Non-ferrous metals</td>
</tr>
<tr>
<td>12</td>
<td>3810</td>
<td>Metal products, except machinery</td>
</tr>
<tr>
<td>13</td>
<td>3820, ex. 3825</td>
<td>Non-electrical machinery, excluding office machinery and computers</td>
</tr>
<tr>
<td>14</td>
<td>3825</td>
<td>Office machinery and computers</td>
</tr>
<tr>
<td>15*</td>
<td>3830</td>
<td>Electrical machinery</td>
</tr>
<tr>
<td>16</td>
<td>3832</td>
<td>Electronics (radio, TV, communication eq., electronic components)</td>
</tr>
<tr>
<td>17</td>
<td>3843</td>
<td>Motor vehicles</td>
</tr>
<tr>
<td>18</td>
<td>3841</td>
<td>Ships and boats</td>
</tr>
<tr>
<td>19</td>
<td>3845</td>
<td>Aircraft</td>
</tr>
<tr>
<td>20</td>
<td>3840, ex. 3843, 3841, 3845</td>
<td>Other transport equipment</td>
</tr>
<tr>
<td>21</td>
<td>3850</td>
<td>Instruments</td>
</tr>
<tr>
<td>22</td>
<td>3900</td>
<td>Other manufacturing</td>
</tr>
</tbody>
</table>

\* Includes sector 16.

performance. In some of the most important world markets, the establishment of a firm market share is only possible for those countries which have the capability to produce innovative products.

Elaborating on Soete (1987) we now ask the more direct question whether or not differences in technological capabilities are systematically related to specialization patterns. The regressions carried out try to explain specialization patterns within each of the 21 sectors considered so far, for a 1985\textsuperscript{12} cross-country sample including all 21 OECD countries in the previous regression. The dependent variable is the Revealed Comparative Advantage (RCA) Index, denoted by A, defined as the country’s share in sector exports over its share in total exports.

The independent variables are defined as follows:\textsuperscript{13}

$W$: the wage rate in current dollars,
Figure 11.3 Regressions explaining the relation between specialization and patenting (RPA)*

* No patent data available for sectors 3, 4 and 22.

\[ I: \text{investment intensity, defined as investment (including buildings), a percentage of value added,} \]
\[ P: \text{Revealed Patenting Advantage (RPA), defined as the country's patenting share in a sector over the country's share in total patenting.} \]

Outcomes of these regressions are summarized in Figures 11.3 to 11.5. On the horizontal axis, sectors are ranked according to R&D intensity, and indicated by their sequence number in Table 11.3. For each of the sectors, the line plotted versus the vertical axis gives the interval \([p - 2e, p + 2e]\), with \(p\) denoting the parameter estimate, and \(e\) its standard error. The little horizontal line in the middle of this interval indicates the parameter estimate itself. Keeping in mind that a \(t\)-statistic of around 1.8 or higher indicates significant (10 per cent or better) estimates, a parameter is significant only if the horizontal axis does not cross the vertical line, or crosses it (very) near to the top or bottom.
Figure 11.4 Regressions explaining the relation between specialization and investment

On the basis of the results, pointing to the relatively good performance of the patenting variable, it seems reasonable to group the sectors by taking the explanatory variables as the criterium. The group which can be labelled 'technology sectors' consists of the following sectors:

Motor vehicles; Instruments; Ships and boats; Non-electrical machinery; Other transport equipment; Other chemicals; Drugs and medicines; Computers and office machinery; Aircraft; Rubber and plastic.

These sectors are the sectors in which patents have a significant positive influence on RCA. These results for these sectors confirm the outcomes found earlier in Soete (1987) and in Dosi, Pavitt and Soete (1990) for the most recent period. It is no surprise to see the high-tech sectors such as instruments, aircraft, computers and pharmaceuticals rank among this group. High-tech exceptions for which no evidence of a positive relation between technology and trade was found are electrical machinery and its sub-sector electronics. Nevertheless, the results highlight (again) that the impact of technology is not limited
Figure 11.5 Regressions explaining the relation between specialization and the wage rate

True values for sectors 5, 6, 13, 14, 16, 17 and 18 are 1000 times the values in the graph.

to these high-tech sectors. We also find positive correlations in more traditional manufacturing sectors, such as motor vehicles, ships, metal products and chemistry.

Next, there are a (smaller) number of sectors for which we have found a positive relation between trade performance and investment. These are the following:

Non-ferrous metals; Textiles, apparel and leather; Wood and products; Paper and printing; Electronics; Non-metallic mineral products.

Finally, we found four sectors in which the wage rate is a significant variable explaining trade performance. These are:

Textiles, apparel and leather; Non-metallic mineral products; Reined oil and oil and coal products; Ferrous metals.

Overall, these results re-establish the importance of technology as a factor in explaining specialization patterns. Thus, they confirm some of the outcomes of the theoretical ideas in section 3. However, the
tests carried out are mainly static by nature, and do not take into account factors with a more dynamic impact. We will take the analysis into a dynamic framework in the next two sections.

5 THE DYNAMICS OF TRADE PERFORMANCE: CONVERGENCE

After the previous section, the most obvious way of trying to explain the dynamics of trade is to test for a relation between the change in some trade performance related variable and the independent variables used in the regressions in the previous section. This is indeed what we have done, relating the first difference of the RCA variable over the 1970–90 period to our technology variable (RPA in 1980), using the same cross-country sector-wise approach as above. We expect to find positive correlations in case the static, structural theory of trade tested above can be extended in a straightforward manner to the dynamic case.

The results in Figure 11.6 indicate that contrary to the analysis in section 4, we find mostly negative coefficients, often significant. These

Figure 11.6 Explaining the change in RCA (1970–90) by a linear regression with RPA in 1980 as the explaining variable
results imply that the countries which can be regarded as technologically strong in a particular sector are also the ones which have experienced a negative change in the trade performance.

Of course, the interpretation that is suggested by these results, i.e., that patenting has a negative influence on the evolution of trade performance, is not altogether valid. Rather, the results seem, as already suggested in the above section, to highlight possible 'long-term' imitative tendencies. The negative coefficients of patents are from this perspective understandable. Think for example of the role of foreign direct investment, with production being transferred to the foreign country, but R&D being carried out in the home country, and patents filed from the main office, resulting in loss of market share or a negative trade balance of the home country, yet continuous technological strength.

The negative correlations between dynamic trade performance and patenting seem from this perspective to indicate that we are not capturing the correct aspects of technological change in the longer run. In line with the arguments on imitation summarized above, this might well be related to the fact that patents in particular are poor indicators of technological imitation. In fact, in the case of strong imitation trends, one could expect that technology flows from the innovative countries (having a strong patenting position) to the imitative countries (weak in patenting), which would indeed cause a negative correlation.

The test that we will use to illustrate this is admittedly simple, and consists of an indirect way of looking for imitation trends in international trade. We follow the method suggested by Ben-David (1991), and also applied in Ben-David’s contribution in this volume. The test starts from the assumption that the evolution of revealed comparative advantages can be described by the following process:

\[
\ln A_{jt} = \psi \ln A_{jt-1},
\]

(1)

If \( \psi < 1 \), the global specialization pattern converges towards a state of no specialization, whereas if \( \psi > 1 \), specialization is reinforced. Moreover, it is convenient to use the values of the parameter \( \psi \) to calculate the number of years (t) necessary to cut the average disparity into two (\( h \), in the case of convergence), or double it (\( d \), in the case of divergence). These two values are

convergence (\( \psi < 1 \)): \( h = \frac{\ln 0.5}{\ln \psi} \)
divergence ($\psi > 1$): $d = \frac{\ln 2}{\ln \psi}$

For each sector $j$, we estimate the equation (1) for a set of panel data for the OECD countries for the years 1971–90. For each sector, we have conducted Chow $F$-tests for structural change in the parameter $\psi$ over time, in order to get an indication of changes in the speed of the convergence/divergence process. In each sector, we assumed a breakpoint (i.e., first year of the second period) for each of the years 1974–88, and calculated the corresponding $F$-statistic.

In Table 11.4 we document for each sector the value of $d$ or $h$ for the estimation for the total period, as well as estimates for separate subperiods in case the $F$-statistic for structural change was significant at the 10 per cent level or higher (we only document the estimations for the break-year which yields the highest $F$-statistic). Numbers between brackets are standard errors of the estimated parameters for $\psi$, and three, two and one star(s) denote significance in a two-tailed $t$-test for the null-hypothesis that $\psi = 1$.

For the regressions relating to the total timespan, there is strong evidence of convergence in every sector, except food (non-significant convergence) and textiles (significant divergence). This means that in general, over the 1970–90 period, specialization patterns in OECD markets for manufactured products have been converging. Although more empirical evidence would be useful to support the conclusion that this is related to the process of (technological) imitation by the originally more backward economies, we feel confident that the evidence presented in Table 11.4 and Figure 11.6 provides a crucial set of points which at least suggests that this has indeed been the case.

Looking at the period-breakdowns in the table, it is obvious that there are a number of sectors in which the converging/diverging trends on specialization have been subject to change over time. There are sectors in which the pace of convergence has slackened (wood; paper and printing; non-ferrous metals; non-electrical machinery; computers; motor vehicles). In light of Figure 11.1 above, these are also the sectors which seem to have contributed to the general macroeconomic trends towards slower convergence. However, there are also sectors in which the convergence process seems to have been speeded up (refined oil; electronics; other transport; instruments), or in which a divergence trend has changed into a convergence trend (other chemicals; rubber and plastic; aircraft). These results are hard to interpret in view of the general macroeconomic climate of slowing convergence in the more recent period.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Total period</th>
<th>Breakpoint (F-stat)</th>
<th>Period 1</th>
<th>Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>con, $h = 105$</td>
<td>none</td>
<td>con, $h = 11$ (0.018**)</td>
<td>con, $h = 75$ (0.010)</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textiles</td>
<td>di, $d = 83$ (0.004**)</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>con, $h = 32$</td>
<td>1976, 3.92**</td>
<td>con, $h = 8$ (0.020**)</td>
<td>con, $h = 44$ (0.008**)</td>
</tr>
<tr>
<td></td>
<td>(0.009**)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper and printing</td>
<td>con, $h = 20$</td>
<td>1975, 11.56***</td>
<td>con, $h = 8$ (0.020**)</td>
<td>con, $h = 44$ (0.008**)</td>
</tr>
<tr>
<td></td>
<td>(0.008***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>con, $h = 29$</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.007***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other chemicals</td>
<td>con, $h = 37$</td>
<td>1974, 12.05***</td>
<td>di, $d = 13$ (0.012***)</td>
<td>con, $h = 22$ (0.009***)</td>
</tr>
<tr>
<td></td>
<td>(0.003**)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refined oil</td>
<td>con, $h = 6$</td>
<td>1980, 8.34***</td>
<td>con, $h = 31$ (0.03)</td>
<td>con, $h = 4$ (0.03***)</td>
</tr>
<tr>
<td></td>
<td>(0.020***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber and plastic</td>
<td>con, $h = 23$</td>
<td>1974, 7.38***</td>
<td>di, $d = 28$ (0.021)</td>
<td>con, $h = 15$ (0.010***)</td>
</tr>
<tr>
<td></td>
<td>(0.009***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-metal minerals</td>
<td>con, $h = 35$</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous metals</td>
<td>con, $h = 13$</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.010***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>con, $h = 15$</td>
<td>1975, 5.69***</td>
<td>con, $h = 7$ (0.030***)</td>
<td>con, $h = 27$ (0.011***)</td>
</tr>
<tr>
<td></td>
<td>(0.011***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal products</td>
<td>con, $h = 11$</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.009***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-electrical machinery</td>
<td>con, $h = 15$</td>
<td>1975, 8.45***</td>
<td>con, $h = 8$ (0.015***)</td>
<td>con, $h = 25$ (0.010***)</td>
</tr>
<tr>
<td></td>
<td>(0.008***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computers etc.</td>
<td>con, $h = 12$</td>
<td>1974, 21.49***</td>
<td>con, $h = 5$ (0.033***)</td>
<td>con, $h = 23$ (0.008***)</td>
</tr>
<tr>
<td></td>
<td>(0.009***)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>Value</td>
<td>Significance</td>
<td>Value</td>
<td>Significance</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Electrical machinery</td>
<td>con, $h = 30$ (0.005***&lt;br&gt;none)</td>
<td></td>
<td>con, $h = 75$ (0.025)</td>
<td></td>
</tr>
<tr>
<td>Electronics</td>
<td>con, $h = 15$ (0.008***&lt;br&gt;1974, 4.66**)</td>
<td></td>
<td>con, $h = 11$ (0.013***&lt;br&gt;1976, 7.84***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
</tr>
<tr>
<td>Motor vehicles</td>
<td>con, $h = 21$ (0.007***&lt;br&gt;1976, 7.84***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
<td>con, $h = 275$ (0.015&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
</tr>
<tr>
<td>Ships and boats</td>
<td>con, $h = 12$ (0.015***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
<td>con, $h = 8$ (0.017***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
</tr>
<tr>
<td>Aircraft</td>
<td>con, $h = 12$ (0.015***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
<td>con, $h = 7$ (0.020***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
</tr>
<tr>
<td>Other transport</td>
<td>con, $h = 20$ (0.010***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
<td>con, $h = 9$ (0.007***&lt;br&gt;1976, 7.28***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
</tr>
<tr>
<td>Instruments</td>
<td>con, $h = 17$ (0.009***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
<td>con, $h = 7$ (0.017***&lt;br&gt;1979, 9.44***&lt;br&gt;1984, 5.85**)</td>
<td></td>
</tr>
<tr>
<td>Other manufactures</td>
<td>con, $h = 49$ (0.007**&lt;br&gt;none)</td>
<td></td>
<td>con, $h = 9$ (0.007**&lt;br&gt;di, $d = 56$ (0.028)</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Asterisks represent t-test significance (see text).*
6 SYNTHESIS AND CONCLUSIONS

This paper has started from the notion that there is a high sectoral specificity in the opportunities and propensities to innovate, and that patterns of inter-sectoral distribution of a country’s innovative strength mostly defy traditional endowment-based explanations. It is against this background of apparent facts and trends that we constructed an alternative view of technology and trade, set out in section 3. Elsewhere, we have utilized these insights on the innovative process as the starting point for the development of a model of trade based on the general existence of technological differences between countries. Against this background, a number of regressions were carried out in section 4, linking technological advantages and specialization patterns (or trade performance) for 22 sectors. In the tests, different degrees of innovativeness and productive efficiency appeared good predictors of the international distribution of trade in most (even some of those not usually considered as high-tech) of the industrial sectors considered.

As was shown in section 3, this analysis can easily be linked with a ‘Keynesian’ view of the determination of the rates of macroeconomic activity of each economy. Unlike standard trade analysis – which generally imposes market-clearing – and unlike Ricardian trade models – which generally assume steady-state growth – the framework suggested assumed changes in the levels of macroeconomic activity of each economy in response to changes in international competitiveness. Thus, the link between technological advantages and world market shares appeared theoretically consistent with a determination of domestic aggregate demand via the foreign trade multiplier. In section 3 we briefly sketched out the relationship between such international differences in technology, inter-sectoral mechanisms of specialization, and macroeconomic growth.

However, as was already concluded in previous work with Dosi and Pavitt (see Dosi, Pavitt and Soete, 1990), ‘it is probably fair to say, that in focusing on the tacit, firm-specific and cumulative features of technological change and the long-term historical evidence of the OECD country’s trade and growth performance, we might have underemphasized some of the international technology diffusion features’. For this reason, section 5 focused in more detail on the possible role of imitation of technological knowledge.

It was found that in almost all manufacturing sectors for which we estimated equations, a catching-up relation was relevant, in the sense that inter-country differences in revealed comparative advantages tend
to become smaller over time. In fact, it appeared that if one did not take into account the effect of imitation, technological performance (measured in the same way as in section 4) would more often than not be negatively related to the evolution of trade performance. This negative relation can probably best be explained by the effects of international relocation of production, including that generated foreign direct investment.

Bringing together the empirical results from sections 4 and 5 leads to some paradoxical results. The short-term static analysis of section 4 clearly illustrated that specialization patterns and comparative advantages are related to differences in technological capabilities between countries. Compared with previous evidence presented in Soete (1981) and Dosi, Pavitt and Soete (1990), the tests carried out in section 4 re-establish this relation for the most recent period (i.e., the mid-1980s).

The dynamic estimations of section 5 on the other hand, point to the fact that in the longer run, imitation is a much more important factor in reshaping specialization patterns than the so-called absolute advantages in terms of R&D inputs or patent outputs in/from the technological process. In other words, and valid for practically all sectors including the most technology intensive ones, we found that countries which initially had a weak trade position in some sector, tended to significantly increase their trade performance over the 1970s and 1980s.

The combination of these two results seems to suggest that the positive correlation between specialization patterns and technological capabilities is gradually wearing off. In other words, the negative feedback effect in the form of imitation is taking the international economic system for one ‘equilibrium stage’ to another. This interpretation stresses the transitory character of the catching-up process in world export markets, similar to arguments made in the literature on long-run growth (Abramovitz, 1992; Soete and Verspagen, 1993; and Figure 11.1 above).

From a more Schumpeterian perspective, however, we would stress that this transitory character does not imply that the system actually settles down in a new equilibrium. Rather, we would expect the imitation process to lead to new technological cumulative advantages (our notion of ‘innovation’), bringing about new patterns of diverging growth (our notion of ‘condivergence’ in growth) at the world level.

From this perspective, it is striking to observe how over the late 1970s and early 1980s, South East Asian NICs have witnessed a dramatic growth increase, leading to significant convergence in growth with Japan, while divergence had been the trend for the 1960s. How-
ever, in terms of technological capabilities (measured e.g. in terms of number of patents granted in the US), the dramatic divergence trend from the 1960s has not been changed into convergence until recently. This is illustrated in Figure 11.7, where we depict the ‘condvergence’ trends for South East Asia over the postwar period. The line representing the trend for GDP per capita is, just as in Figure 11.1 above, the average distance to the frontier value of per capita income, in this case Japan. The line representing the patenting trend gives the concentration index for patenting, defined as the inverse of the entropy coefficient applied in section 4, with shares in total South East Asian (including Japan) US-patents used as input.

The shape of the patenting series is caused by the fact that, initially, the number of patents granted to South East Asian NICs remained extremely low, while those granted to Japan increased at a very rapid rate. Clearly, imitation was at the basis of the NICs’ convergence relative to Japan. However, since the mid-1980s, something of a reversal seems to have occurred: catching-up growth rates of South East Asian countries have reduced substantially. By contrast, and in terms of technological capabilities, growth of South East Asian countries’ patenting has increased dramatically: convergence to Japan
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seems to be on its way here (see also the contribution of Dosi and Freeman in this volume).

In other words, the process of innovation (i.e., the strategy to build up own innovative capacities based on previously imitated accumulated knowledge) does not lead to further convergence but to a process of increased international trade specialization and in all likelihood a future process of growth divergence.

Notes

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2. See e.g. Landes (1969), Ames and Rosenberg (1963), Habakkuk (1962) and von Tunzelmann (1978).

3. These are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom, USA.

4. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, United States. Source of all the data is OECD.

5. This opens up questions with regard to causality, which we do not further explore here.

6. In a formal context, this is represented by Thirlwall’s (1979) ratio of income elasticities, which multiplies the rate of growth of world income by a number larger or smaller than unity to arrive at a country's individual growth rate of real income.

7. We fully acknowledge the fact that (new) neoclassical models are capable of generating much more interesting dynamic behaviour than just the steady state, and admit that space considerations force us to generalize more on this topic than might be appropriate. However, we feel that, by and large, the mainstream attention to the steady state underestimates the usefulness of other approaches to growth.

8. Although only three countries are used in the calculations of R (because of data availability reasons), we use 21 countries in the calculations for entropy. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States. Source of all the data is OECD.
9. As the sectors will also be used in regressions below, we also document one sector which is not in the current regression. This is the sector 'ships and boats'.

10. See Kamien and Schwartz (1982) for an overview.

11. For implementation of the Schumpeterian ideas, see Kamien and Schwartz (1982); for an overview of these ideas in the new growth theories, see Verspagen (1992b).

12. We do not take into account lags, which might lead to inaccuracies when the world we are looking at is not too stable. Moreover, due to missing values in the data, most of the regressions with other than RCA and RPA variables are done for a sample of less than 21 countries.

13. The source of the data is OECD, except for patenting, for which the source is the US patent office. In line with previous analysis (Soete, 1987) we will systematically use the patenting activity of countries in the USA, the most important technology market in the world. The reason for using a 'relative' RPA index rather than some 'absolute' measure of patenting (such as patenting per head) lies in the fact that because of 'home advantage', the US share in patenting is biased upward. For more details and justification for using this variable, see Soete (1987).

14. We thank William D. Nordhaus for suggesting this method of presentation to us.

15. R&D intensities are the ones used in the regression above, only for the year 1985. We do not have data on R&D intensity for the sector 'ships and boats', and accordingly place it at the beginning of the sequence.

16. Note that in a number of other sectors, one finds a positive relation between trade performance and the wage rate. This relation, which usually vanishes if one takes into account other variables such as investment of technology, can be interpreted as evidence on the impact of differences in skill levels.

17. Taking averages over the total period does not change the results.

18. For example, why is Switzerland strong in pharmaceuticals and Sweden in mechanical engineering? See also Pavitt and Soete (1982).

References


Thirlwall, A.P. (1979) ‘The Balance of Payments Constraint as an Explana-
tion of International Growth Rate Differences’, *Banca Nazionale del Lavoro*, vol. 32, pp. 45–53.


