6

Technology gaps, cost-based adjustments and international trade

As we have observed, particularly from the broad literature review in Chapter 2, the century of economic discussion which focussed on the allocative optimality for given and identical technologies has somewhat obscured the importance of differences in techniques between countries, and has neglected the analysis of their origin and their effects. As we illustrated in the preceding chapter, it is quite plausible that the wide international differences in per capita income might be due primarily to differences in the degree of capital accumulation and differences in technology rather than just differences in relative prices.

The investigation of these phenomena has, however, developed separately from trade theory, which, until recently, did not take technology gaps as one of the fundamental facts from which to start theorising. This applies, as we saw in Chapter 2, in different ways to both neo-classical and classical theories. The former have generally excluded from the core of the model the implications of straightforward inferiority/superiority of techniques and products between countries for the validity of the most general theorems (such as international factor price equalisation or even the demonstration of the gains from trade) to hold. The latter, in principle, allows the existence of such international technological differences, but takes a rather general and agnostic view, describing the equilibrium specialisations irrespective of the specific nature of the techniques available in each country.

The recent literature on technology-gap explanations of international trade – as we also saw in Chapter 2 – has developed quite independently from the classical (e.g. Ricardian) analysis of the relationship between absolute and comparative advantages. A few syntheses have been attempted between technology-gap models and traditional factor endowment theories, the so-called 'neo-technology' theories, whereby the number of primary factors is increased to include some technology-related ones also.

The hypothesis put forward here, though, is that technology-gap explanations of trade flows are essentially accounts of the impact of different absolute advantages upon competitiveness which can be reconciled within a classical framework of cost-based adjustments. At the core of our explanation are the *technological differences* between countries which as we will attempt to illustrate, also determine the boundaries of the universe of all cost-based adjustments.

In other words, the analysis starts from the opposite assumption to that of the prevailing neo-classical theory. The latter, in its standard form, assumes technological identity between countries. We, by contrast, assume technological differences between countries as the main 'stylised fact' from which we begin theorising. Empirical and theoretical arguments for this choice have already been put forward in the preceding chapters. To name a few: against any 'revisionist' use of neo-classical trade theory, there are the inner logical flaws of factor-endowment theories (cf. the famous Cambridge debate on capital theory), the lack of empirical support for the theory (by any standard the so-called Leontief 'paradox' should be understood as a falsification of the theory), and, perhaps even more important, the evidence about technology and technical change, discussed in Chapter 4, which suggests that the international distribution of innovative activities is uneven.

As we then argued in Chapter 5, technology gaps can be more adequately represented by unequivocal differences (i.e. superiority/inferiority) in techniques and in products, which are not in any direct sense an endowment, but closely related to the process of capital accumulation, the outcome of processes of discovery, learning, imitation and improvement.

Here we shall suggest an interpretative model of trade flows based on international and intersectoral technological differences. In Section 6.1 we shall consider the interplay between technology gaps, wage gaps and national comparative advantages. In Section 6.2 we explore further the notion of *competitiveness*, distinguishable from comparative advantages and related to the participation of each country to international trade flows. The effects on competitiveness of absolute advantages, wage differences and different forms of industrial organisations will be analysed. In Section 6.3 we present an empirical analysis of the determinants of export performances by sector and by country. Finally, in Section 6.4, we discuss some evidence on the dynamics of technological advantages, cost-based competitiveness and export trends.

6.1 Technology gaps, wage gaps and comparative advantage

A number of implications can be drawn immediately from the analysis of technical change in Chapters 4 and 5.

First, widespread technological asymmetries between countries relate in the first instance to the capability of some countries to produce innovative commodities (i.e. commodities which other countries are not yet capable of producing, irrespective of relative costs) and to use process innovations more efficiently or quickly in the reduction of input coefficients.

Second, the nature of technical progress is such that processes of factor substitution are of minor importance at any given level of technological knowledge.

Third, international differences in labour productivity appear to express adequately technology gaps in relation to techniques that can often be unequivocally ranked as superior and inferior (more/less efficient) independent of input prices.

Fourth, the relationship between wages and productivity is generally a good measure of those factors of competitiveness which are related to costs and prices. In other words it can be considered as an approximation of the 'Ricardian' adjustment process, taking place on the basis of given international technological asymmetries (stemming from different innovative and imitative capabilities).

These points can easily be illustrated by re-interpreting the international 'evolutionary equilibria' discussed in Chapter 5. Take the simple case of when the intrasectoral, international technological gap is determined only by process innovations, affecting labour productivity while leaving the capital/output ratio unchanged. Figure 6.1 represents a hypothetical industry whose world demand is *DD*. For simplicity, we assume that there are only three countries and each national industry is characterised by only one firm.

As a first (but empirically reasonable) approximation – which we consider to be not that far from reality – assume that in the short term techniques are fixed and that there is no actual choice of technique: each country will stick to the best technique that it is able to master. This best technique is defined primarily by the country's technological competence and is, in this first approximation, independent of relative prices. This also implies that there are techniques which are unequivocally more efficient but are not used by every country, except the technological leader, due to asymmetric competence.

Such technological asymmetries induce international differences in labour productivity (without, however, affecting capital/output ratios).[1]

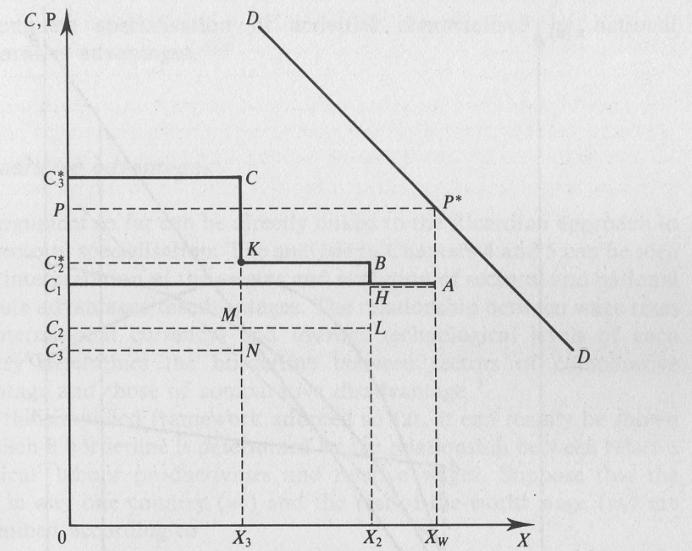
Country 1 is the most advanced country, while country 3 is the most backward one. If each country had the same wage rates (expressed in international currency) as country 1, the line C_3^*CKBHA would represent unit variable costs for countries 3, 2 and 1, respectively. At an identical international price equal to *P*, country 3 could not even produce economically ($C_3^* > P$). However, wages vary across countries. The broken line C_3NMLHA, representing the actual unit wage costs, illustrates an extreme case of competitiveness reversal due to such differentials, which more than compensate for the technological asymmetries. The most advanced country is also the least competitive ($C_1 > C_2 > C_3$).

The relationship between technological levels and wage rates

Figure 6.1 illustrates how international competitiveness is determined by the relationship between sectoral absolute technological advantages and wage rates. It is impossible to deal here in any satisfactory depth with the theory of income distribution which implicitly underpins such a model of trade.[2] Let us just mention the hypothesis that, given the country-specific institutional factors which affect the determination of wages and profits (such as the modes and levels of industrial conflict, the nature of the labour markets, the patterns of competition, etc.), wages in terms of international currency are determined by the relationship between domestic rates of macroeconomic activity and the average technological advantages/disadvantages vis-à-vis foreign economies in the tradeable sector.[3] We would even adopt a more restrictive hypothesis and take the view that in the long term for each economy or – in broad international comparative terms – between countries, the pattern of absolute average technological levels is the dominant factor explaining the trends (and the international differences) in wage rates (see also Chapter 7, below).[4]

One can now reinterpret the example illustrated in Figure 6.1 in the following way: owing to the *functional dependence of wage rates* (in international currency) *on average absolute technological advantages/disadvantages* (average of the tradeable sector as a whole), the diagram represents an extreme case where the *comparative* advantage (as expressed by the relationship between sectoral and average technological advantages) takes over from the pattern of competitiveness determined by sector-specific technological lags and leads.

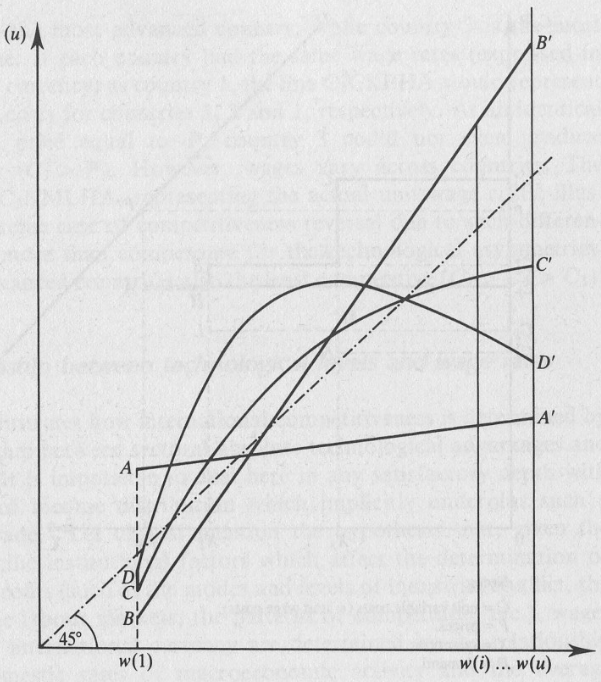
Figure 6.2 illustrates possible forms of such a relationship between technological advantages and wage rates. Let us imagine a continuum of countries (ordered in relation to wage rates represented on the *x*-axis). The corresponding labour productivities are represented on the *y*-axis.



Notes:
C = unit variable costs (= unit wage costs).
P = prices.
X = quantities.
D = demand.

Figure 6.1 Technological asymmetries and international differences in wage rates

All the points below the 45° line show unfavourable competitiveness and vice versa. The lines *AA'*, *BB'*, *CC'*, *DD'* correspond to hypothetical sectors. In sector *A* the countries with higher productivity and higher wages are also the least competitive. The opposite applies to sector *B*. Finally, sectors *C* and *D* show higher levels of competitiveness in the intermediate groups of countries. Which case will apply depends on the relationship between degrees of international technological asymmetries and international wage differences. So, for example, the line *AA'* describes a sector characterised by relatively low asymmetries (say, due to low appropriability of technological advances) in a world characterised by relatively higher wage gaps. Conversely, in the sector represented by *BB'*, appropriability is relatively high, technological asymmetries are large and technology gaps dominate over wage advantages. Of course, the corresponding line for a hypothetical sector with



Notes:
u = countries.
π = labour productivity.
w = wage rates in international currency.

Figure 6.2 Productivity and wages in a 'continuum of countries'

sectoral technological gap/lead for each country identical to the country's average gap/lead would also run the 45° line cutting the quadrant, and no country would display a 'comparative advantage' in that activity.

It is easy to extend the analysis to a variety of different firms in each country. As we argued in Chapter 5, interfirm technological asymmetries are an essential feature of each country's industry. Suppose for simplicity that technological coefficients are normally distributed across firms in each country. Then, the input coefficients of each country are averages of a distribution whereby there can always be a 'tail' of highly competitive firms in an 'uncompetitive' national industry, and *vice versa*. Hence, one can also account for the empirically observed lack

of complete specialisation in activities characterised by national comparative advantages.

Comparative advantages

The argument so far can be directly linked to the Ricardian approach to intersectoral specialisation. The analysis in Chapters 4 and 5 can be seen as an interpretation of the origins and evolution of sectoral and national absolute advantages/disadvantages. The relationship between wage rates (in international currency) and *average* technological levels of each country determines the borderline between sectors of comparative advantage and those of comparative disadvantage.[5]

In the simplified framework adopted so far, it can readily be shown that such a borderline is determined by the relationship between relative 'physical' labour productivities and relative wages. Suppose that the wage in any one country (w_j) and the rest-of-the-world wage (w_t) are determined according to

$$w_j = \sigma_j \sum_i \pi_{ij} s_{ij} \qquad \textbf{(6.1)}$$

and

$$w_t = \sigma_t \sum_i \pi_{it} s_{it} \qquad \textbf{(6.2)}$$

where the πs are labour productivities, the ss are the sectoral shares in output, the σs are the 'distributive coefficients' linking wages and average productivities, and the suffixes i, j, t stand for the sectors, the countries and the world respectively.

The sectors of national advantage/disadvantage will then be ranked according to

$$\frac{\pi_{ij}}{\pi_{it}} > \ldots > \frac{w_j}{w_t} > \ldots > \frac{\pi_{nj}}{\pi_{nt}} \qquad \textbf{(6.3)}$$

where the wage of country j relative to the world wage (w_j/w_t) represents the border line between comparative advantages and disadvantages.

So far, our analysis simply shows how in principle an *evolutionary microstructure*, continuously yielding interfirm and international asymmetries, can be directly linked to a classical (Ricardian) approach of comparative advantage: any country will find its comparative advantage in the sector where its technological gap is proportionally smaller (or the lead greater) and vice versa.

6.2 National trade performance: absolute advantages and absolute measures of competitiveness

We now address the question of the extent to which the role of *absolute* technological advantages is limited to determining the wage rate and comparative advantage. We shall argue that absolute advantages have different, even more important, effects.

Some public good features of absolute advantages

Consider the (more complex and more realistic) case where different pieces of technological knowledge and different inputs enter the production process of each tradeable commodity. Given the discussion in Chapter 4 on some of the cross-industry and cross-technology interdependencies, it will come as no surprise that most technological capabilities have some *public good* (or 'externality') features, which are essential to the organisation of production and innovation. One can think of the (maybe trivial) technological capability of making machines work or handling electricity supplies: irrespective of comparative advantages, every nation and firm must rely on these capabilities. Similarly, in the division of labour between individuals, coordination and administrative activities have analogous public input features, irrespective of the set of activities which are undertaken within an organisation.

At a higher level of abstraction, *dominant* technologies play a similar role in that they shape the technological and productive efficiency in a wide set of sectors, no matter what the comparative advantages are. In all these cases, as highlighted by MacDonald and Markusen (1985), the sole knowledge of comparative advantages (either between individuals or between countries) is not a sufficient predictor of actual (or 'optimal') allocations. As they point out:

> ...it is not persuasive that the employee with the highest comparative advantage in management should become president. Indeed it is plausible that the presidency assignment will have something to do with absolute advantages; alternatively a person with poor management skills will not be chosen even if he is relatively worse at every other task in the firm. Further, in academic economics, generally poor economists will not be chosen as department chairman even if they have a comparative advantage in these activities relative to research and teaching ... . A prediction that follows from Ricardian and Heckscher-Ohlin comparative-advantage models is that identical economies will not trade. Yet, that countries with apparently similar technologies and factor endowments seem to trade large volumes of manufactured goods with one another can be taken as evidence that assignments do not depend entirely on comparative advantages. Indeed, trade arising from scale economies in models with identical countries, is now referred to as 'non-comparative advantage trade'... . That specialisation may be optimal independent of differences in comparative advantages is a special case of a more general failure of the comparative advantage principle to predict assignments. (MacDonald and Markusen, 1985, pp. 278–9)

In terms of the analytical framework presented here, the implication is that whenever there are strong technological interdependencies, hierarchical links between technologies and externalities (in terms of cross-sectoral fertilisations, spill-overs, etc.), the pattern of absolute advantage in these dominant technologies, skills or capabilities will have to be taken as an autonomous determinant of international competitiveness, independent of the pattern of comparative advantage.

Moreover, 'comparative advantage will tend to be a poor proxy for optimal assignment when differences in absolute advantages are large relative to differences in comparative advantages'.[6] Recalling the empirical analysis in Chapter 3, this is, generally speaking, the case for most contemporary economies: the *intersectoral intranational* differences in technological capabilities, although significant, tend to be of smaller orders of magnitude than international differences.

The notion of absolute advantage requires a redefinition of *competitiveness*. Clearly, in a Ricardian or Heckscher–Ohlin world, every country, by definition, must be relatively competitive in something. Competitive in this sense amounts, however, to little more than a tautology: being competitive might simply mean that anyone is bound to be less bad in something and worse in something else. Conversely, the externality features of absolute advantages (in the form of country-specific technological capabilities and institutional arrangements) imply that:

> The competitiveness of a national economy is more than the simple outcome of the collective 'average' competitiveness of its firms; there are many ways in which the features and performance of a domestic economy viewed as an entity with characteristics of its own, will affect in turn the competitiveness of the firms. (OECD 1985, p. 6)

Absolute competitiveness and comparative advantage

A direct impact of absolute advantages upon competitiveness requires something like an absolute notion of competitiveness. According to

Cohen, Teece, Tyson and Zysman:

> International competitiveness at national level is based on superior productivity performance and the economy's ability to shift output to higher productivity activities, which in turn can generate high levels of real wages ... . It is not just a measure of the nation's ability to sell abroad, and to maintain a trade equilibrium. The very poorest countries in the world are often able to do that quite well. Rather it is the nation's ability to compete internationally in those commodities and services likely to constitute a larger share of world consumption and value added in the future. (Cohen, Teece, Tyson and Zysman, 1984, p. 2)

Similarly, Mistral argues that

> ... competitiveness is the expression of a global property (both micro and macroeconomic) specific to each national economy – the efficiency with which each country mobilises its factorial resources and, in so doing, modifies the technical and social characteristics of industrial activity. At the same time, competition on world markets as a whole (domestic and foreign) reveals the success of those national performances relative to each other: the more advanced and competitive economies then exert an external constraint on the others through the pattern of foreign payments balances. (Mistral, 1983, p. 2)

Mistral calls this feature of national economies 'structural competitiveness'.

The two concepts of 'structural' (or absolute) competitiveness and that of 'relative' (intersectoral) comparative advantage point to some tangled and rather complex issues of economic analysis.

The core of trade theory has generally attempted to answer the question: 'What explains comparative advantages?' and the complementary question: 'Are there gains from trade?' An answer to these questions has traditionally also meant an answer to another question, namely: 'What explains the international composition of trade by country, i.e. the participation of each country in trade flows?' In the classic Ricardian example, the analytical identification of the two questions is straightforward: comparative advantages and specialisation explain the entire amount of trade occurring between England and Portugal in wine and cloth. In the simplest case, trade even yields absolute specialisations. This line of thought, and even more so in the neo-classical approach, puts the main emphasis on the question of the gains from trade.

Our analysis on the other hand suggests that the two questions must be theoretically separate. Take two countries of comparable size but with different degrees of technological and economic development: the advanced country will generally show a higher participation in world trade in the sectors of comparative disadvantage than will the backward

country in the sectors of comparative advantage.[7] It is certainly interesting to understand why the world-market share of country 1 in product x is, say, 10 per cent, while it is 11 per cent in product y. However, it is also interesting (and certainly more relevant to macroeconomic issues) to understand why country 1 has that 10 per cent share in product x while another country, n, has only a 0.1 per cent share in the same product, despite the fact that the sector might well be one of 'comparative advantage' to country n, whose product y only has 0.05 per cent of the world market. The concept of absolute competitiveness relates to the explanation of issues such as: Why has country 1 a market share of 10 per cent in product x (and, not, say, 5 per cent or 20 per cent)? or: Why has country 1 an average world-market share of, say, 10.8 per cent? Conversely, the concept of comparative advantage relates to issues (more familiar to economists and a little awkward to practitioners) such as: Why is the revealed comparative advantage of country 1 in product x equal to 10/11 of that in product y?

Our hypothesis is thus that absolute advantages *dominate* over comparative advantages as determinants of trade flows. Their dominance means that they account for most of the composition of trade flows by country and by commodity at each point in time and explain the evolution of such trade flows over time.[8]

This dominance takes two forms. First, absolute advantages/disadvantages are the fundamental factors which explain sectoral and average competitiveness, and, thus, market shares. Second, they also define the *boundaries* of the universe within which cost-related adjustments take place. As we saw in the preceding chapters, intersectoral, intranational differences in technological levels are of an order of magnitude smaller than intrasectoral, international differences. Thus, the boundaries of the adjustments linked to comparative advantages and relative sectoral profitabilities are rather tight: *a fortiori*, the dominance argument applies.

Adjustments in market shares and adjustments in sectoral specialisation

The distinction between the two concepts relates in the first instance to different *adjustment* mechanisms at work within each economy and in the world markets. Let us consider these in some detail.

Suppose we start from an international set-up whereby each industry is on an international evolutionary equilibrium, as defined in Chapter 5. Each national foreign account – assumed for simplicity to be equal to the trade account – is balanced; each national wage is proportional to the average technological level of the tradeable part of the economy; and there is some unemployed labour in each economy.[9] Suppose that, due to some innovative success, any one country j improves its relative productive efficiency (limited here to labour productivity) in sector i, while all others remain unchanged.[10] In other words, we have an increase in the absolute advantage (or a decrease in the absolute disadvantage) for country j in sector i. What will happen?

First, an increased technological capability in sector i, relative to foreign competitors, will lead to an increase in the world-market shares of country j in that sector.

Second, the average technological level of country j improves approximately by:

$$\frac{\Delta \pi_{ij} s_{ij} + \pi_{ij}\, \Delta s_{ij}}{\sum_i \pi_{ij} s_{ij}}$$

Wages (in international currency) will consequently tend to adjust correspondingly. This will occur in three ways: (a) through the effect that higher world-market shares have on domestic growth via foreign-trade multipliers and the resulting impact of higher growth on the domestic labour market; (b) through the effect of the higher competitiveness on the exchange rate; and (c), finally, through the institutional mechanisms which in most contemporary economies link productivity growth and wage increases.

Third, the domestic allocation of investment and employment will lead to a relative increase in investment and employment in sector i and an absolute increase in all employed resources. This will be the joint result of the increased competitiveness of sector i vis-à-vis the rest of the world and an increase in the relative profitability of sector i vis-à-vis the other domestic sectors.

Fourth, there *might* be some changes in the price of product i relative to other products (this is more likely to occur if country j is large in relation to the world).

Strictly speaking, the comparative advantage mechanisms of adjustment relate to the intersectoral changes in the allocation of resources, pulled by changed profitabilities and relative prices. Conversely, competitiveness-related mechanisms of adjustment also have macroeconomic dimensions, such as changes in the *absolute* amount of employed resources, rate of growth, wage rates and exchange rates.

At the end of these various adjustment processes, country j will have a higher world-market share in i; a higher rate of macroeconomic activity and higher wages; somewhat lower world-market shares in sectors other than i; a higher revealed comparative advantage (or lower revealed comparative disadvantage) in i; and a higher average world-market share for the country as a whole. As an illustration of this last point, imagine as an extreme case that all mechanisms of adjustment just mentioned occur, except that wages (in international currency) do not adjust upwards (recall that we have assumed the general existence of unutilised labour). In this case we will eventually see a higher world-market share for country j in sector i and *unchanged world-market shares* in all other sectors. More likely will be the case where the 'gains of competitiveness' will be distributed between higher growth and higher wages. This will, however, not alter our conclusion: the higher share in sector i will more than compensate for the fall in the other sectors.

We leave the more formal analysis of the relationship between technology, trade, specialisation and growth to Chapter 7. Here it is important to note how the foregoing example highlights the distinct roles of absolute advantages and absolute competitiveness, on the one hand, and revealed comparative advantages (more rigorously – revealed relative allocations) on the other. The former is reflected by the link between international technological asymmetries in sector i and national market shares in that same sector, and the link between average national technological asymmetries and average national shares in world markets. Conversely, relative intersectoral allocations result from the intersectoral differences of these sector-specific gaps and leads.

In the illustration given above it is easy to see how these two questions are fundamentally different. Consider in the foregoing example, the post-adjustment pattern of revealed comparative advantages. As we saw, this was the result of an absolute increase in the technological level of sector i, leaving all others unchanged. However, the same pattern of revealed comparative advantage could also have been achieved as a result of a *fall* in the technological level (compared to other countries) in all sectors except i, that is, through a general fall in competitiveness, market shares, and rates of growth. Finally, consider the case of a proportional improvement of technological levels in all sectors. Here we do not have any comparative advantage effect. Instead, the export market shares will grow in all sectors and the country-wide increase in competitiveness will result in higher growth and higher wages.

The reader might recall the analogy between this case and our interpretation of the argument by 'heretic' trade theorists, reviewed in Chapter 2: adjustment to changing country-specific absolute advantages leads to changes in competitiveness, market shares and real incomes, irrespective of the pattern of comparative advantage. More generally, this leads to the proposition that: the international pattern of sectoral absolute advantages/disadvantages is a fundamental determinant of sectoral competitiveness as expressed by the sectoral market shares of each country.[11]

The latter are influenced by comparative advantages only in so far as the differences between sectoral and average gaps and leads affect the relative cost structures and profitabilities of each sector. However, we suggest that the main adjustment mechanism to changes in the pattern of absolute advantages/disadvantages (under normal conditions of non-decreasing returns, reproducible capital inputs and less than full employment of world labour) does not occur through changes in relative quantities and relative prices in each economy, with unchanged levels of macroeconomic activity, but through changes in world-market shares and (relatedly) in the total level of employed resources and in the levels and rates of growth of incomes and wages. As we shall see in Chapter 7, this argument can easily be linked with a Keynesian open-economy model.

This proposition can best be illustrated with reference to the famous Ricardian example of trade in wine and cloth between England and Portugal. Our reformulation of the technology-gap model, based on some of the patterns of technical change analysed in Chapter 4, explains why the Portuguese coefficients of production are 'better' than the English ones, and uses this difference to explain both the participation of each country in trade and the pattern of revealed comparative advantage. Our hypothesis is that the former is primarily explained by absolute advantages. In other words, and staying with the Ricardian example, a major part of the explanation of the pattern of international production and trade in, say, cloth, can be simply inferred by looking at the size of the technology gap in cloth between Portugal and England. Conversely, comparative advantage only accounts for that part of the international distribution of production and trade stemming from the difference between sectoral and average technology gaps for each country.

A comparative advantage mechanism, based on relative prices and relative profitabilities is still undoubtedly at work and will contribute to the explanation of relative specialisations. However, as is implicit in technology-gap theories, the dominant effects run from technology gaps to domestic levels of production, exports, and income. In other words, any absolute measure of the international competitiveness of a country or industry is primarily based on its absolute advantages/disadvantages in terms of product technology and labour productivity. This property finds an intuitive corroboration in the 'stylised facts' presented in Chapter 3. There it was found that long-term changes in the export market shares of each country were often general to all or most sectors.

Our model suggests that these changes are in fact due to country-wide changes in absolute advantages/disadvantages.

A technology-gap model of international competitiveness

Formally, one can specify sectoral trade performance as a function of both technological absolute advantage (T_{ij}) and variable costs (C_{ij}):

$$X_{ij} = f(T_{ij}, C_{ij}) \tag{6.4}$$

where X_{ij} is some indicator of international competitiveness (related to the size of exports in sector i for each country j); T_{ij} represents an indicator of technological levels (both product and process technologies in the same sectors i for each country j) and C_{ij} represents a proxy for variable costs e.g. labour costs (as we shall see, either wage rates or unit labour costs, depending on the specification of the model).

Even if the income distribution between wages and profits is neglected in this simple relationship, we suggest that the latter can nevertheless be taken to represent the proximate determinants of international competitiveness fairly well. This hypothesis can be justified on the basis of our earlier analysis in Chapter 5 on the choice and change in techniques. To recall, we showed there that technical progress tends to be more or less Harrod-neutral. It should be clear that we are not claiming that technical progress is precisely neutral – through time or across countries. For our purposes here, it is sufficient that its possible international or intertemporal biases are of an order of magnitude smaller than international gaps in labour productivity and technological innovativeness,[12] and that there is no *a priori* reason to expect the capital intensity biases to be systematically correlated with degrees of technological development.[13] This is also supported by the fact that capital goods tend to have a (nearly) unique international price; that international differences in profitability are indeed of an order of magnitude smaller than differences in wage rates[14] and that they also do not appear to show any correlation with degrees of development or relative capital endowments.[15]

Taking all these considerations together, one may safely conclude that in all sectors which do not have a high intensity of natural resources (such as minerals, energy, etc.), differences in wages will mostly capture those international differences in input prices which do not stem directly from varying degrees of technological efficiency.

Equation (6.4) can therefore be considered to capture the effects of both sectoral absolute technological gaps (through the variable T) and 'comparative advantages' (through the variable C, specified as unit labour costs) on 'absolute' competitiveness (approximated, for example, by world market shares or per capita exports).

In order to illustrate this, let us suppose that each country is in what one could call a 'macroeconomic' foreign-balance equilibrium: given a certain average (for the tradeable sector as a whole) technological gap vis-à-vis other countries, the relationship between the levels of wages, the exchange rate and the rates of macroeconomic activity is such that their foreign accounts exactly balance. For simplicity, suppose also that there is no capital account and that all external trade is in manufactures.

As mentioned earlier, if we had an industrial sector representative of the average technological gap of every country, this sector would show identical unit labour costs in international currency for all countries (see Figure 6.2 in Section 6.1).[16] Thus, such a 'representative sector' would present productivity gaps equal to wage gaps in every country (see equations (6.1) and (6.2)) and unit labour costs would be identical across countries. The sector would therefore also represent the border line between sectors of revealed comparative advantage and disadvantage. However, other sectors may well still show international differences in unit wage costs. If adjustment processes are not instantaneous and if, as is likely, the sectoral input coefficients and technological levels are averages of distributions between different firms, we can expect the sectors of comparative advantage to show relatively lower unit costs (compared to other countries in the same sector), and *vice versa* for sectors of comparative disadvantage.

One can imagine a plausible situation in which each economy is permanently in a state of microeconomic disequilibrium: technical change takes place all the time; technological diffusion processes are rather slow; and demand lags in response to international price changes are significant. In some way, one is always in the middle of an adjustment process. Under these circumstances, the effects of intersectoral patterns of comparative advantage can be detected without the knowledge of the notional pre-trade values of the variables.[17] A country will find an incentive to expand its export in those sectors where it has a relative cost-based advantage, and vice versa.

Let us now relax the assumption of a macroeconomic foreign balance equilibrium. For a given average technological gap, each country is allowed to have 'disequilibrium' wage rates, expressed in international currency (or, which is the same, disequilibrium exchange rates), yielding an across-the-board competitive advantage for some countries and disadvantage for others. In this case, the 'representative sector' would also show international differences in unit wage costs, while in all other sectors the unit wage cost differences would be increased/reduced by a proportion expressing the degree of macroeconomic disequilibrium. In the model presented here, the unit wage cost variable will therefore capture two effects, both stemming from cost-related adjustments; first, the degree of comparative advantage/disadvantage of each country in each individual sector; and second, the cost-based general advantage/disadvantage each country experiences through what could be called an undervalued/overvalued currency.

Forms of industrial organisation and international competitiveness

Let us now go back to equation (6.4). As it stands, it captures the proximate determinants of international competitiveness, as revealed by export performance. However, the discussion so far has been based on the simplifying assumption that forms of industrial organisation are neutral in relation to the effect on competitiveness of given technology gaps and wage gaps. In reality this will rarely be the case.

On theoretical grounds, as one of us has argued elsewhere (Dosi, 1984), the *history* of technological and economic development of an industry and of each individual company has an important influence upon the present competitive position of each company (and, by implication, each country), independent of present relative technological capabilities and present cost conditions. More precisely, the history of the technological development of a company and – in general – the history of its relative competitive success vis-à-vis other companies is also the history of market shares, market power, geographical diffusion, distribution networks, accumulation of goodwill, and diversification and differentiation of production.[18] All these variables affect *present* competitive performances on both domestic and international markets in ways which may be partly independent of present relative technological capabilities and relative costs.

The role of industrial organisation becomes even more important when one introduces international investment. In other words, present national and international industrial organisation forms are a reflection of the *cumulative result* of past technological advantages/disadvantages and of the ways in which firms have exploited their behavioural degrees of freedom throughout their competitive history. As a striking illustration, one may take, at least until recently, the competitive performance of a firm such as IBM (and, through it, of the United States) in computers. A good part of the reason for this performance rests in its present technological and cost advantages. However, its history of international penetration, its organisation, industrial market power, etc., also play an important part.

The non-neutrality of the forms of industrial organisation with respect to the amount, composition and even direction of trade flows is a relatively robust result which is also obtained from neo-classical models, whereby either firms enter into strategic price/quantity interactions of the Cournot type, or the market is characterised by imperfect (Chamberlinian) competition.[19] *A fortiori*, we would expect this non-neutrality to apply to the complex evolutionary world that we are analysing here, where firms differ not only in size but also in technological capabilities, and where the past has a strong inertial effect upon the present and the future since it is sedimented in organisational structures, behavioural rules, fixed investments, etc.

In this context, it is interesting to observe a couple of empirical facts. First, export propensities often appear to be directly related to firms' sizes for reasons which do not show a straightforward link with *technological differentials*;[20] second, the abundant evidence on intra-industry (and intrafirm) trade, indirectly at least, points to the role of international oligopolistic competition and market structures in shaping trade patterns;[21] and third, the evidence, as contradictory as it may seem about the export-complementarity vs. the export-substitution effects of foreign investment, also highlights the non-neutrality of this form of international industrial organisation with respect to trade patterns.[22]

From a dynamic point of view, industrial organisations are of course the essential actors in technological accumulation, innovation and imitation. This also means that both industrial structures and technological gaps/leads are endogenous to the competitive dynamics of each country but that they evolve along patterns which cannot generally be expected to show a simple linear relationship to each other.[23]

Within a dynamic context, the influence of industrial organisations on a country's international competitiveness emerges even more strongly. As suggested by Cantwell (1983), on the basis of Dunning's (1981) eclectic approach, international investment is one of the forms of adjustment by firms which aim strategically to exploit privately appropriated absolute advantages. The important point for our discussion here is that the form of exploitation (direct investment vs. export) influences both the evolution of competitiveness – on a country-basis – and the pattern of national technological accumulation. Current investment decisions with respect to the location of production, R&D, etc., influence the national patterns of trade but also the technological capabilities (and, over large numbers) the cost conditions of each country. In turn, all this influences both the general competitiveness of 'parent' and 'host' countries and also the future locational advantages/disadvantages. Nothing, of course, prevents, *a priori*, these dynamic loops between corporate strategies and national/regional characteristics entailing either 'virtuous' or 'vicious' loops (Cantwell and Dunning, 1986).

The long-term effect of inward and outward multinational investment on export competitiveness depends in the last resort on whether foreign production and exports are substitutes or complements. This is a tangled controversy which cannot be discussed in any detail here. Suffice it to say that the model of technical change developed earlier (Chapter 4) implies that complementarity is more likely to occur when appropriability of technological advances is high, and/or when user–producer linkages are internalised within single firms. In this case, when marketing networks represent some kind of common asset for local production and exports, the 'crowding-out' of local firms resulting from foreign investment will be high and economies of scale (in either R&D, production or sales) will be significant. Under these circumstances, foreign direct investment is likely to pre-empt the foreign markets and, often, reproduce through time the initial pattern of country-specific advantages/disadvantages[24] (see Dosi, 1984, for a more detailed discussion of this issue).

A general model of the determinants of international competitiveness

In view of these considerations, equation (6.4) above must be modified in order to account for the additional effect that the forms of industrial organisation have upon international competitiveness.

Let us rewrite equation (6.4) as follows:

$$X_{ij} = f(T_{ij}, C_{ij}, O_{ij}) \tag{6.5}$$

Ideally, the independent variables should capture the set of technological advantages/disadvantages (T_{ij}); international differences in variable costs – primarily labour costs – (C_{ij}); and the sectoral forms of industrial organisation (O_{ij}), e.g. the domestic market structure, the degree and forms of participation in international oligopolies, whenever they exist, etc. In other words, O_{ij} stands for that set of organisational specificities (in terms of size, degrees of internationalisation, etc.) of each national industry as compared to foreign competitors in the same sector.

At each point in time, the international competitiveness of each economy in each sector (e.g. export shares or exports per capita) is determined by the technological gap/lead of that economy, by its wage gap and by the forms of *industrial organisations* which are, in a sense, the structural result of the past history of relative innovativeness and relative competitiveness.

A priori, we may expect the relative impact of these three variables to differ between sectors. Those sector-specific features which affect the process of generation and diffusion of innovations discussed earlier (see

Chapter 4), also determine the size of the international technological gap and the way the organisational structures influence trade flows.

In science-based and specialised supplier sectors, for example, we would expect international innovative gaps to be critical to competitiveness and, thus, the *T*-variable to be of overwhelming importance. In scale intensive sectors (e.g. cars) various kinds of economies of scale, product technology, labour productivity and organisational forms can be expected to be important. Finally, in supplier-dominated sectors with relatively simple, readily available technologies (e.g. textiles), we would expect international competitiveness to be determined essentially by labour costs (that is, by the relationship between capital embodied technology and wage rates).

A way of reformulating the foregoing discussion is by reference to Figure 6.2 above. In Section 6.1 we analysed the link between technology gaps and wage gaps in so far as it determined national revealed comparative advantages. From Figure 6.2 it appeared that country *i* had a comparative advantage in the sector represented by *BB′*, and that country 1 had a comparative advantage in *AA′*. However, the question addressed here is different. We now ask what determines international competitiveness – as reflected by market shares or export per capita within, say, sector *BB′* or *AA′*. Equations (6.4) and (6.5) account for these determinants of competitiveness. It is now possible, and indeed likely, that country *i* will also have a higher market share than country 1 in sector *AA′*, its sector of comparative disadvantage.

Let us consider this sector in more detail, and assume for realism that on the *y*-axis of Figure 6.2 we represent both product-related and process-related technological asymmetries. We know that in sector *AA′* country *i* has a technological lead (although not a big one) and a cost disadvantage vis-à-vis country 1. Equation (6.5) tells us how much the technological, organisational and cost advantages count in determining international competitiveness (and, thus, world-market shares).

The taxonomy discussed above (see Chapter 4) allows for some predictions in this respect. For example, in sector *AA′*, which can be taken to represent supplier-dominated industries, cost of production (and thus cost advantages/disadvantages) are likely to be important. The opposite would apply to science-based sectors.

The general structural (in Mistral's definition) competitiveness of each economy can also be represented by:

$$X_j = F(T_j, C_j, O_j) \tag{6.6}$$

where the variables without the *i*-suffix are the sum of, or weighted, averages across each country. In a notional state of macroeconomic

equilibrium (defined earlier in this chapter) the C_j variable – when expressed in terms of unit labour costs – will tend to be identical across countries, while overvalued or undervalued currencies would be reflected in differences in the C_js. Still, the wide international differences in the absolute technological advantages and in the forms of industrial organisation determine the wide variance in the levels of competitiveness of each economy (measured by market shares or per capita exports). In a sense, the specific functional form of the relation between competitiveness, on the one hand, and technological accumulation, capital investment, process-efficiency and organisational structure, on the other, expresses the degree of fitness of each national economy to the prevailing international pattern of growth and trade (Mistral, 1982 and 1985).

In other words, revealed comparative advantage (that is, the actual distribution of exports between sectors) is the ratio of two absolute measures of competitiveness, namely sectoral competitiveness and competitiveness for the economy as a whole. That is:

$$RCA_{ij} = \frac{f_j(T_{ij}, C_{ij}, O_{ij})}{F(T_j, C_j, O_j)} \tag{6.7}$$

where RCA_{ij} is the index of revealed comparative advantage of country *j* in sector *i* and the variables *T*, *C* and *O* have the same meaning as in equation (6.5). Thus, equation (6.7) a more analytical expression of the usual formula:

$$RCA_{ij} = \frac{X_{ij}/\Sigma_j X_{ij}}{\Sigma_i X_{ij}/\Sigma_i \Sigma_j X_{ij}}$$

Under competitive conditions, the variable (*O*) would become irrelevant. Similarly, if absolute advantages/disadvantages between countries tended to disappear, the variable (*T*) would lose much of its importance in explaining sectoral and country-wide competitiveness. Recalling that the wages that appear in the numerator of unit costs (*C*) are a function of average productivity (cf. equations (6.1) and (6.2)), equation (6.7) would tend to shrink to:

$$RCA_{ij} = f_i\left(\sigma_j \frac{\Sigma_i \pi_{ij} s_i}{\pi_{ij}}\right) \tag{6.8}$$

This is equivalent to the formula we obtained earlier with respect to comparative advantage (equation (6.3)), illustrating that the determination of comparative advantage and of sectoral competitiveness become one and the same thing only under competitive conditions *and* with technological similarity between countries.

The dynamics of international competitiveness

Equation (6.5) above represents the determinants of international competitiveness at any given time. From a dynamic point of view, however, the dependent and independent variables interact with each other: different levels of international competitiveness affect the evolution of industrial organisations, their capability to innovate/imitate, the exploitation of economies of scale and of learning curves, etc. In other words, industrial organisations have to be treated dynamically as endogenous variables within the international competitive process. Furthermore, the time profile of the technology gaps will also depend on some of the forces affecting the relative rates of innovation and diffusion and, thus, also on the changing levels of opportunity, cumulativeness and appropriability that each technology presents. Finally, labour costs depend essentially on macroeconomic factors, related to the evolution of average technological levels, rates of macroeconomic activity, and institutional features of the labour market and industrial conflict.

In other words, there will be an entire *set* of paths that the dynamic counterpart of equation (6.5) might follow, of which product-cycle evolutions of international competitiveness and widening technological gaps are the two extreme cases: which path is actually followed will depend on country-specific conditions (such as the rates and directions of the patterns of national technological accumulation, trends in wage rates, capital accumulation, etc.) as well as on sector-specific conditions (such as changes in the degrees of opportunity, appropriability, complexity, etc., of each technology).

Following Silverberg (1987) and re-interpreting it in relation to the present model we suggest the following dynamic process, derived from equation (6.5):

$$\dot{X}_{ij} = A(E_{ij} - \bar{E})X_{ij} \qquad \textbf{(6.9)}$$

where the dots stand for the rates of change; X_{ij} are world-market shares; E_{ij} encompasses the factors of competitiveness T, C, O; and $\bar{E}$ is the weighted 'competitiveness' of the world market ($= \Sigma_i X_{ij} E_{ij}$).

In general the long-term trade performance of each country is determined by the dynamics of its E_{ij} as compared to the world average. Consider in particular the T-components of E (i.e. technology-related variables) and suppose that they are summarised by a vector μ_{ij} with $E_{ij} = E(\mu_{ij})$. Hence, country-specific and sector-specific dynamics of competitiveness depend on the transition probabilities in the μ_{ij}: $P[(\mu_{ij} + \varepsilon) \mid \mu_{ij}]$. But what explains these transition probabilities and their differences across countries and across sectors? Here one can see the full importance of the interpretative categories discussed in

Chapter 4 in relation to technical progress. It is precisely the different degrees of opportunity, cumulativeness, appropriability of technical advances which account for different rates of change in competitiveness across countries and across sectors. For example, one can infer that, if technical progress is very cumulative, for any two pairs of countries 1 and 2:

$$P[(\mu_{i1} + \varepsilon) \mid \mu_{i1}] \geqslant P[(\mu_{i2} + \varepsilon) \mid \mu_{i2}] \qquad \textbf{(6.10)}$$
$$\text{for } \mu_{i1} \gtreqless \mu_{i2}$$

Success in this case tends to breed success and the process will lead to diverging trends in competitiveness, formally similar to those cumulative processes analysed in Arthur (1985) and (1988). Similar conclusions hold for high levels of appropriability of innovative capabilities. The opposite holds for low cumulativeness and appropriability. In these cases the model predicts a more likely convergence in the levels of competitiveness of the various countries and also less unevenly distributed market shares.

Finally, high technological opportunities imply, other things being equal, a relatively high rate of change in the μ_{ij}s and thus in E_i, with an effect on the dynamics of distribution of the E_{ij} (i.e. on the dynamics of international asymmetries). That, again, depends on the cumulativeness of technological advances, the easiness of imitation, reverse engineering, technological transfer, possibilities of 'leapfrogging', etc.

Rigorously, equation (6.5) and its dynamic counterpart (6.9) should represent the state (and/or change in) of the variables on the right-hand side with regard to both each industry in question and the vertically integrated sector which directly or indirectly enters the production of the exportable commodity X_i (see in more detail Momigliano and Siniscalco, 1984). As in our earlier discussion (Chapter 4) of the complex thread of technological flows between sectors, this should come as no surprise: input–output and technological interdependencies transmit the effects of absolute advantage/disadvantage well beyond the industry where they originated. In a sense, these interdependencies are a fundamental link between sectoral competitiveness and the general competitiveness of each economy as a whole. It is not possible to pursue that issue further here, but there seems to be no *a priori* reason why the foregoing interpretative framework could not be extended to a model that explicitly accounts for intersectoral commodity flows.

To summarise: equation (6.5) can be interpreted as the joint account of the effects on international competitiveness of absolute technological and organisational advantage/disadvantage, and, only in a second instance and indirectly, of comparative advantage (as revealed by relative variable costs). In other words, when one measures sectoral competitiveness (say, sectoral market share in world exports), this is an 'absolute' measure of competitiveness (it is certainly relative to other countries, but independent from other sectors within the same country). It is also the relevant variable which one needs in relation to the analysis of macroeconomic growth (Harrod's multipliers, etc.). This measure of competitiveness depends, we argue here, on technology, on costs and on forms of industrial organisation.

Comparative advantages, on the other hand, depend on the intersectoral comparisons of the technology and organisational gaps, within the same country. Thus, the sectoral ('absolute') measure of competitiveness can be notionally divided into two parts: that part which is common to all tradeable sectors (the 'average' gap) and that part which is sector-specific. A country can be bad in everything and a bit less bad in something, or vice versa. Moreover, there is a sectoral specificity of the importance of technology, wage costs and organisations. In some sectors, wage gaps may compensate (or more than compensate) for the technological gaps and this may determine a relatively high international competitiveness. In other sectors, the international market might put a high premium on innovativeness, quality, product and process sophistication, so that even a unit cost advantage, in the presence of a technological gap might still be reflected in a low level of international competivitiveness. Similarly, in some sectors (which we grouped under the heading 'scale intensive'), size, international investments, worldwide marketing networks, differential capabilities of managing complex structures of production and service will represent the most powerful sources of competitive advantage. Within other sectors (especially the so-called 'specialised suppliers' sectors), flexibility, location-related externalities and user–producer linkages are likely to provide the organisational advantages.

Trade theory has generally focussed on the (intranational, intersectoral) comparative aspects of trade flows. Here we have suggested that one should really start by explaining the origins and effects of the absolute gaps/leads which are sector-specific and are the core element in explaining trade flows. Comparative advantage is in some sense a residual result – although an important one since it generates those intersectoral signals (relative profitabilities, etc.) which contribute to shaping the allocation of resources.

Patterns of demand and patterns of trade

A final set of comments concerns the relevant world and domestic

demand conditions. The model suggested above is essentially a supply-side one, in the sense that it attempts to give an explanation for sectoral and country-wide competitiveness in the world market, on the basis of the differential supply conditions that each country is confronted with in each sector (and as a whole). On the other hand, the structure of demand, domestically and as between trading partners, is an important factor in explaining average import propensities and the geographical destination of trade flows. This is one of the main approaches of trade theories, along the lines of Linder and Barker.[26] *A priori* there is no inconsistency between the technology-gap model discussed above and these demand-based models. The latter tend to explain the size and growth of each sectoral market and its geographical distribution between countries (which is taken to be a function of income per capita, product characteristics, etc.). In our approach, on the other hand, these markets are taken as 'given', and it is the international distribution of supply in terms of the technological, cost and organisational characteristics of the various national industries within the same sector which is explained.

Dynamically, the link between the two models is close: as we saw in Chapters 4 and 5, the demand and supply factors behind the diffusion of innovations are not at all independent; the conditions of each domestic market influence the patterns and rates of technological accumulation; user-producer and, more generally, input–output links influence the generation and diffusion of innovation throughout the economy. Thus, Andersen *et al.* (1981) present evidence that domestic demand conditions can induce technological advantage in supplying sectors.[27]

At a more macroeconomic level, the evolution of national competitiveness is influenced by the evolution of sectoral patterns of demand. Let us recall equation (6.6). The total export share of each country is a weighted average of each sectoral share. The change over time of such total country-shares is the result of the effects of sectoral gaps/leads upon sectoral competitiveness, but also of changing sectoral weights. In turn, the change in these sectoral weights depends on the evolution of patterns of world demand and of relative prices.

National relative specialisations (which determine the sectoral weights in each country) have an important effect on the long-term evolution of competitiveness in so far as they determine the degree of consistency between national points of strength and weakness and changing world demand conditions.[28] In the last resort, this depends on the world income elasticities of the various commodities, relative to national specialisations. Consider, for example, the following, rather extreme example. Suppose we have two countries, Portugal and England, which export wine and cloth. At time zero, Portugal exports $8 of wine out of a world exports total of \$10 and \$2 of cloth out of a world exports total of \$20. Conversely, England exports \$1 of wine and \$9 of cloth. Obviously, the sectoral competitiveness and the patterns of specialisation differ between the two countries, but their country-wide competitiveness measured by their world-market shares is identical: $(8 + 2)/(10 + 20) = (1 + 9)/(10 + 20) = 1/3$. Suppose now that at time 1 the sectoral competitiveness of Portugal in wine increases, so that it exports, say, \$9 out of an unchanged world market of \$10, while the English competitiveness falls to a market share of

$$\frac{\$0.5}{\$10}$$

Conversely, suppose that the Portuguese share in cloth grows: say it exports \$21 out of an increased world-market value of \$200, while the English one falls slightly, with exports growing only to \$85. From this sectoral evidence, it would appear that English competitiveness has fallen and Portuguese competitiveness has increased. However, due to very different patterns of world demand, the total English market share has now grown to

$$\frac{0.5 + 85}{10 + 200} \approx 41 \text{ per cent}$$

while the Portuguese one has actually fallen to

$$\frac{9 + 21}{10 + 200} \approx 18 \text{ per cent}$$

As Lafay (1981) points out, it is this dynamic implication of the patterns of specialisation which makes them analytically important, well beyond the once-and-for-all gains in efficiency that openness and specialisation generally bring about in the usual static context of trade theory.[29] Thus, following Rothschild (1985) and to some extent in analogy with our discussion on technology gaps, one could define the 'structural demand-determined gap' as the (positive or negative) difference between actual world export growth and that notional world export growth which would have resulted if world exports had kept the same intercommodity weights as the country in question.

When we allow for the possibility of intersectoral shifts in the composition of world demand, and, at a finer level of disaggregation, the possibility of intrasectoral shifts among products with different characteristics, quality, etc., the path followed by the country-wide counterpart of equation (6.9) may well lead to diverging national trends in the C-variable (representing unit labour costs), with constant average technological gaps. Other things being equal, one country may still gain in overall competitiveness, even with rising average unit labour costs, to

the extent that this is associated with a movement towards inter- and intrasectoral specialisation characterised by higher quality and sophistication, higher value added per physical unit of output and/or higher income elasticity of demand.[30] The opposite may apply to countries with a worsening quality of their pattern of specialisation.

6.3 Some tests on the determinants of export performance

A complete empirical test of the model outlined in the preceding section, both in its cross-sectional and dynamic forms would require a relatively wide set of data that are not generally available. Thus, with respect to equation (6.4), one would need comparable sectoral and country data for a number of technologies or technological performance indicators (product-embodied technology, process technology, labour productivity, input efficiencies, etc.); some sectoral measures of labour costs per physical unit of homogeneous output; and a variety of 'market structure' indicators, ranging from firm size, concentration, degrees of foreign ownership, levels of internationalisation, etc., again all specified at the sectoral level. Such data are not yet available. The approach chosen here thus aims, in the first instance, at providing a broad set of empirical tests and results – much constrained by available statistical data – which could form the basis for further empirical research in this area based on more complete and reliable statistical data.

Technology and trade patterns: some evidence

Let us first consider a set of tests of the form

$$X_{ij} = f(T_{ij}) \tag{6.11}$$

where the *T*s stand for a number of proxies related to sectoral and country-specific technological advantages/disadvantages. The econometric evidence reported here is based in the first instance on some earlier empirical research by one of the authors (see Soete, 1980 and 1981a), interpreted here, however, in the light of the theoretical framework developed above and in the preceding chapter.

As we already saw earlier (Chapter 3) patenting in the United States appears to be a reasonably good indicator of the innovative performance of each country within single sectors. We use this variable here as a proxy for the sectoral innovativeness of a country. Variations in export performance across the various OECD countries[31] (X_{ij}, where $j = 1$–22)

will be regressed on variations in innovativeness (P_{ij}) for each of forty 3-digit industrial sectors $i (i = 1\text{–}40)$. The choice of sectors was dictated by the US patent data source.[32] The testing procedure (across countries within each industry) is analogous to that pioneered by Leamer (1974) and Lacroix and Scheuer (1976).

Moreover, in the estimates we shall consider some variables also used by these authors, namely population, GDP, the country-wide capital/labour ratio and a 'resistance' variable, i.e. a distance proxy from export markets. Our interpretation of these variables is different, however, from theirs. On the grounds of the foregoing discussion we shall consider these variables (with the exception of 'distance') as proxies for a set of country-specific absolute advantages which tend to affect, to different degrees, all sectors in any one particular country. In other words, in our interpretation population will tend to capture the potential economies of scale that can be achieved on the domestic market; GDP on the other hand will be a more mixed indicator of size and degree of development, whereas the capital/labour ratio is assumed to be a proxy for the degree of capital accumulation and thus also of the automation or mechanisation of production achieved in the economy at large.[33]

Multicollinearity problems between the population and the GDP variable on the one hand,[34] and the GDP and patent variables on the other hand,[35] forced us to drop the GDP variable. A regression equation where the dependent variable is weighted by GDP (equation (6.13) below) was, however, also estimated. The following four sets of regression equations were estimated for each of the forty industries i:

$$\ln XSHA_{ij} = \beta_{0i} + \beta_{1i} \ln PSHA_{ij} + \beta_{2i} \ln KL_j + \beta_{3i} \ln Pop_j + \beta_4 D \textit{ is } t_j \qquad \textbf{(6.12)}$$

$$\ln RCA_{ij} = \beta_{0i} + \beta_{1i} \ln PSHA_{ij} + \beta_{2i} \ln KL_j + \beta_{3i} \ln Pop_j + \beta_{4i} D \textit{ is } t_j \qquad \textbf{(6.13)}$$

$$\ln \frac{(X_{ij})}{(M_{ij})} = \beta_{0i} + \beta_{1i} \ln PSHA_{ij} + \beta_{2i} \ln KL_j + \beta_{3i} \ln Pop_j + \beta_{4i} D \textit{ is } t_j \qquad \textbf{(6.14)}$$

$$\ln \frac{(X_{ij})}{(GDP_j)} = \beta_{0i} + \beta_{1i} \ln PSHA_{ij} + \beta_{2i} \ln KL_j + \beta_{3i} \ln Pop_j + \beta_{4i} D \textit{ is } t_j \qquad \textbf{(6.15)}$$

where,

$XSHA_{ij}$ = share of each country's j exports of industry i (X_{ij} in total OECD exports of industry i ($\Sigma_{j=1}^{22} X_{ij}$)

$$RCA_{ij} = X_{ij} \Big/ \sum_{j=1}^{22} X_{ij} : \sum_{i=1}^{40} X_{ij} \Big/ \sum_{i=1}^{40} \sum_{j=1}^{22} X_{ij}$$

and

X_{ij} = exports of country j for product i;

$\Sigma_{j=1}^{22} X_{ij}$ = OECD exports (excluding Iceland) for product i

X_{ij}/M_{ij} = ratio between the exports of country j for product i and the imports of country j for product i (M_{ij})

X_{ij}/GDP_j = share of exports of country j for product i in the gross domestic product of each country j

$PSHA_{ij}$ = share of each country's j 1963–77 US patents in industry i (P_{ij}) in total OECD (including the estimated US figure (see Chapter 3) 1963–77 US-registered patents in industry i) ($\Sigma_{j=1}^{22} P_{ij}$)

KL_j = gross fixed capital formation divided by total employment for each country j

Pop_j = population of each country j

$Dist_j$ = Linnemann's distance proxy (1966, p. 186, Table 7.4, using I_i (0.8)) which is a proxy for the physical distance of various countries from some assumed 'world centre'.

In so far as these empirical tests aim in the first instance at providing more corroborative evidence of some of the structural characteristics of trade among OECD countries, the particular year chosen is not of real importance to the analysis presented here. In order to allow for some comparison with the analyses carried out previously by one of us (Soete, 1980, 1981a), all variables have been calculated for the same year, 1977. However, to avoid large variations in annual numbers – for some countries the number of annual patents granted in particular industries will be extremely small – the patent variable was calculated for the period 1963–77. Our analysis, in other words, does not make any claim to be updated; its aim is not to provide an explanation of the most recent trade patterns following recent changes in competitiveness. Rather, it provides a picture of what have been the major determinants of trade competitiveness in the post-War period, in this case the mid-1970s.

The best results were obtained for regression equation (6.12). This is not surprising: it is in terms of export shares (i.e. competitiveness) that one would expect to find the clearest indication of the effects of the various sector-specific and country-specific advantages. In terms of revealed comparative advantage indices, where the commodities' export shares are being weighted by the overall export share, one might expect a far less clear picture to the extent that interindustry variations in export performance are being introduced in the dependent variable. Nevertheless, the results for equations (6.13), (6.14) and (6.15), while less significant overall, are similar to the results presented in Table 6.1.

A number of interesting features emerge from these results:

1. Overall non-significant results (non-significant F values) were obtained for three industries: food, agricultural chemicals, and petroleum and natural gas – all industries where one might assume that natural resource endowments play a crucial role. Because no such variable was included in equation (6.12), the non-significant results obtained for these industries should come as no surprise.
2. As regards the capital/labour ratios, their country-average is clearly an imperfect proxy for sectoral capital intensity. The lack of significance with regard to this variable should again come as no surprise. Nevertheless, the significance of this variable in some of the continuous-process industries where one would expect process technology and capital equipment to be important for competitiveness (see plastics and synthetic materials, petroleum and natural gas, non-ferrous metals) is striking.
3. Population, as used here, captures both the size and scale effects of large countries. It is interesting to note that most significant results are obtained for stone, clay and glass products, fabricated metal products, refrigeration and service machinery and motor vehicles – all industries in which *economies of scale* play an important role.
4. As noticed by Gruber and Vernon (1970), proximity to the major foreign markets is still a crucial advantage in many industries. The distance variable performs relatively well in most industries.
5. Last but not least, the results in Table 6.1 bring to the forefront the crucial role of the technology variable in explaining the intercountry variations in export performance in a large number of industries. With the exception of the 'natural resource intensive' industries (food, petroleum, agricultural chemicals and stone, clay and glass) and a number of industries where *patented* innovations can be expected to be less of an appropriate proxy for innovativeness (such as textiles, ships and boat building, motorcycles and bicycles), significant results are obtained for all other industries.

Furthermore, a ranking of the industries by their estimated 'technology' elasticities (β_1) reveals a number of interesting facts.[36] First, as illustrated in Table 6.2, the ranking of the various industries is relatively independent of the equation chosen. While the estimated technology elasticities for equations (6.13) and (6.14) are in general less significant,

Table 6.1 Estimates of regression equations explaining OECD countries' export shares for forty industrial sectors*

Dependent variable ln $XSHA_{ij}$ for industries j:	β_0	β_1 ln $PSHA_{ij}$	β_2 ln KL_i	β_3 ln Pop_i	β_4 $Dist_i$	$\bar{R}^2$	$F(4, 17)$
1. Food products	-5.01	0.099	0.402	0.368	0.004	0.32	3.52
	(2.69)	(0.147)	(0.588)	(0.255)	(0.003)		
2. Textile mill products	-12.90*	0.145	-0.337	0.631**	0.011*	0.73	15.15*
	(2.19)	(0.117)	(0.551)	(0.230)	(0.003)		
3. Industrial inorganic chemicals	-8.10**	0.488**	-0.128	0.522	0.003	0.78	19.53*
	(2.97)	(0.197)	(0.849)	(0.393)	(0.004)		
4. Industrial organic chemicals	-8.66*	0.238	0.712	0.776**	0.013**	0.82	25.37*
	(2.63)	(0.114)	(0.539)	(0.262)	(0.003)		
5. Plastic materials, synthetics	-2.55	0.305*	1.143**	0.344**	0.008*	0.91	51.16*
	(1.99)	(0.098)	(0.477)	(0.225)	(0.002)		
6. Agricultural chemicals	-11.36	0.256	0.457	0.939	0.009	0.20	2.34
	(8.24)	(0.385)	(1.607)	(0.785)	(0.009)		
7. Soaps, cleaners, toilet goods	-0.49	0.325**	1.261	0.382	0.009**	0.69	12.67**
	(3.65)	(0.158)	(0.656)	(0.334)	(0.004)		
8. Paints and allied products	-0.69	0.214	1.585*	0.478	0.010**	0.68	12.15*
	(3.79)	(0.164)	(0.538)	(0.338)	(0.004)		
9. Miscellaneous chemical products	-4.33	0.226	0.743	0.492	0.006**	0.67	11.61*
	(2.83)	(0.137)	(0.627)	(0.289)	(0.003)		
10. Drugs	-5.22**	0.340*	0.164	0.278	0.011*	0.77	11.41*
	(2.57)	(0.108)	(0.495)	(0.252)	(0.003)		
11. Petroleum, natural gas	3.22	-0.151	3.581**	1.071	0.009	0.36	3.96
	(7.76)	(0.362)	(1.363)	(0.827)	(0.008)		
12. Rubber and miscellaneous plastic products	-7.63*	0.441*	-0.038	0.424**	0.009*	0.86	33.38*
	(2.11)	(0.121)	(0.573)	(0.210)	(0.002)		
13. Stone, clay, glass and concrete products	-11.58*	0.220	-0.129	0.679*	0.009*	0.81	23.97*
	(1.88)	(0.113)	(0.489)	(0.191)	(0.002)		
14. Primary ferrous metal products	-4.71**	0.417**	0.577	0.514	0.005**	0.84	28.69*
	(2.32)	(0.146)	(0.842)	(0.265)	(0.003)		

Continued

Table 6.1 *(Continued)*

Dependent variable ln $XSHA_{ij}$ for industries j:	β_0	β_1 ln $PSHA_{ij}$	β_2 ln KL_i	β_3 ln Pop_i	β_4 $Dist_i$	$\bar{R}^2$	$F(4, 17)$
15. Primary and secondary non-ferrous metals	0.94	0.262**	1.154**	0.316	0.001	0.81	23.36*
	(2.02)	(0.118)	(0.533)	(0.234)	(0.002)		
16. Fabricated metal products	−7.68*	0.346*	0.107	0.502*	0.008*	0.88	40.34*
	(1.81)	(0.090)	(0.468)	(0.180)	(0.002)		
17. Engine and turbines	−4.71	0.473**	1.250	0.843**	0.008**	0.31	23.52*
	(3.32)	(0.213)	(0.765)	(0.382)	(0.004)		
18. Farm and garden machinery equipment	−3.37	0.657*	0.704	0.530	0.005	0.78	19.52*
	(3.98)	(0.223)	(1.022)	(0.349)	(0.004)		
19. Construction, mining material handling machinery equipment	−7.44**	0.512*	0.117	0.527	0.007**	0.84	28.31*
	(2.74)	(0.154)	(0.749)	(0.257)	(0.003)		
20. Metalworking machinery and equipment	−8.93*	0.650*	−0.562	0.287	0.009*	0.34	28.35*
	(2.74)	(0.133)	(0.709)	(0.293)	(0.003)		
21. Office, computing and accounting machinery	−7.95	0.392**	−0.509	0.238	0.014**	0.65	10.90*
	(6.36)	(0.320)	(1.591)	(0.630)	(0.007)		
22. Special industry machinery	−4.49	0.676*	−0.051	0.191	0.007**	0.86	33.60*
	(2.80)	(0.146)	(0.729)	(0.264)	(0.003)		
23. General industrial machinery	−6.09**	0.494*	0.340	0.494**	0.009*	0.87	36.72*
	(2.67)	(0.112)	(0.642)	(0.232)	(0.003)		
24. Refrigeration and service machinery	−8.30**	0.513*	0.618	0.858*	0.006	0.84	28.46*
	(2.94)	(0.146)	(0.629)	(0.271)	(0.003)		
25. Miscellaneous machinery excluding electrical	−0.37	0.930*	−0.248	−0.211	0.007**	0.87	36.67*
	(2.97)	(0.166)	(0.768)	(0.301)	(0.003)		
26. Electrical transmission and distributing equipment	−3.14	0.672*	−0.230	−0.230	0.008**	0.81	23.03*
	(2.93)	(0.174)	(0.797)	(0.334)	(0.003)		
27. Electrical industrial apparatus	−1.39	0.615*	0.134	0.040	0.004	0.78	19.18*
	(3.32)	(0.190)	(0.878)	(0.401)	(0.004)		
28. Household appliances	−4.68	0.501*	0.109	0.184	0.004	0.78	20.09*
	(2.46)	(0.132)	(0.618)	(0.248)	(0.003)		
29. Electrical lighting, wiring equipment	−3.37	0.509**	0.373	0.245	0.009**	0.77	19.05*
	(3.47)	(0.219)	(0.992)	(0.488)	(0.004)		
30. Miscellaneous electrical equipment supplies	−4.71	0.412*	0.702	0.578**	0.006**	0.88	40.76*
	(2.27)	(0.119)	(0.551)	(0.264)	(0.003)		
31. Radio, TV receiving equipment	−5.58	0.503	−0.97	0.170	0.009	0.61	9.13*
	(4.48)	(0.254)	(1.185)	(0.580)	(0.005)		
32. Communication equipment, electronic components	−8.29**	0.463**	0.009	0.499	0.010*	0.80	22.36*
	(2.59)	(0.172)	(0.862)	(0.343)	(0.003)		
33. Motor vehicles and equipment	−9.45*	0.456**	0.732	1.027*	0.007**	0.86	32.85*
	(2.88)	(0.162)	(0.724)	(0.310)	(0.003)		
34. Ship, boat building, repairing	1.15	0.529	0.808	0.089	0.003	0.38	4.21**
	(5.68)	(0.348)	(1.388)	(0.582)	(0.006)		
35. Railroad equipment	−14.95**	0.133	1.154	1.557**	0.015**	0.62	9.71*
	(5.49)	(0.239)	(0.988)	(0.542)	(0.006)		
36. Motorcycles, bicycles and parts	0.54	0.530	1.898	0.575	0.012	0.60	8.87*
	(6.63)	(0.282)	(0.998)	(0.599)	(0.007)		
37. Miscellaneous transportation equipment	6.29	0.799*	1.186	−0.189	0.011**	0.80	21.51*
	(4.12)	(0.199)	(0.764)	(0.404)	(0.004)		
38. Ordnance, guided missiles, space vehicles and parts	−5.09	0.900*	−0.982	−0.108	−0.001	0.53	6.88*
	(5.79)	(0.277)	(1.118)	(0.570)	(0.006)		
39. Aircraft and parts	1.09	1.262*	−0.206	−0.307	0.009	0.91	22.67*
	(4.50)	(0.242)	(0.891)	(0.449)	(0.005)		
40. Instruments	−6.94	0.743*	−0.611	0.109	0.010**	0.80	22.82*
	(3.53)	(0.184)	(0.944)	(0.343)	(0.004)		

Notes:
* Significant at the 1% level.
** Significant at the 5% level.
The figures in parentheses are the estimated standard errors of the coefficients.
For the SIC-definition of these industries and their conversion into SITC product codes see Soete (1981).

Source: Soete, L. (1981).

Table 6.2 Ranking of the technology variable's elasticities β_1

Industries[a]	Equation 6.12	6.13	6.14	6.15
Aircraft	1.26	0.97	0.87	1.19
Miscellaneous machinery	0.93	0.67	0.73	0.83
Ordnance and guided missiles	0.90	0.77	0.52	0.82
Office equipment	0.89	0.64	0.52	0.83
Miscellaneous transportation equipment	0.80	0.54	0.76	0.73
Instruments	0.74	0.47	0.57	0.67
Special industry machinery	0.68	0.43	0.64	0.62
Electrical transmission and distributing equipment	0.67	0.38	0.54	0.58
Farm and garden machinery	0.66	0.38	0.57	0.57
Electrical industrial apparatus	0.62	0.40	0.55	0.55
Metalworking machinery	0.57	0.41	0.43	0.49
Ship, boat building[b]	0.53^{+}	0.30^{+}	0.32^{+}	0.47^{+}
Motorcycles and bicycles[b]	0.53^{+}	0.32^{+}	0.33^{+}	0.47^{+}
Refrigeration and service machinery	0.51	0.27	0.35	0.43
Construction and mining machinery	0.51	0.24	0.39	0.43
Electrical lighting, wiring equipment	0.51	0.30^{+}	0.27^{+}	0.40
Radio and TV receiving equipment[b]	0.50^{+}	0.27^{+}	0.17^{+}	0.41^{+}
Household appliances	0.50	0.25	0.38	0.41
General industrial machinery	0.40	0.30	0.40	0.43
Industrial inorganic chemicals	0.42	0.25^{+}	0.48	0.43
Engines and turbines	0.47	0.28^{+}	0.46	0.40
Communications equipment and electronics	0.46	0.17^{+}	0.35	0.39
Motor vehicles	0.46	0.18^{+}	0.32^{+}	0.39
Rubber and plastics products	0.44	0.14^{+}	0.33	0.37
Ferrous metal products	0.42	0.24^{+}	0.32^{+}	0.33
Miscellaneous electrical supplies	0.41	0.21	0.31	0.34
Fabricated metal products	0.35	0.09^{+}	0.26	0.28
Drugs	0.34	0.18	0.25	0.26
Soap, cleaners	0.33	0.14^{+}	0.18^{+}	0.27
Plastic materials	0.31	0.08^{+}	0.22	0.25
Non-ferrous metal products	0.26	0.14^{+}	0.13^{+}	0.19^{+}
Agricultural chemicals[b]	0.26^{+}	0.03^{+}	0.28^{+}	0.18^{+}
Industrial organic chemicals[b]	0.24^{+}	0.08^{+}	0.13^{+}	0.17^{+}
Miscellaneous chemicals[b]	0.23^{+}	0.06^{+}	0.14^{+}	0.17^{+}
Stone, clay and glass[b]	0.22^{+}	−0.08^{+}	0.05^{+}	0.14^{+}
Paints[b]	0.21^{+}	0.01^{+}	0.18^{+}	0.15^{+}
Textiles[b]	0.15^{+}	−0.12^{+}	−0.10^{+}	0.07^{+}
Railroad equipment[b]	0.13^{+}	−0.06^{+}	−0.05^{+}	0.05^{+}
Food[b]	0.10^{+}	−0.16^{+}	−0.14^{+}	0.02^{+}
Petroleum products[b]	−0.15^{+}	−0.25^{+}	−0.13^{+}	−0.22^{+}

Notes:
[a] Industries ranked by the technology variable's elasticity in equation (6.12), as given in Table 6.1.
[b] Overall *not* significant at the 10% level (t-statistic).
$^{+}$ *Not* significant at the 10% level (t-statistic).

Source: Soete (1981a).

their ranking is very similar to the estimated elasticities for both equations (6.12) and (6.15).

Second, in contrast to Lacroix and Scheuer's findings (1976), the ranking of the technology elasticities suggests – with some important exceptions – a relationship with 'technology intensity': not so much R&D-intensity, but some measure which also gives weight to the technological performance of the various machinery industries, such as patent-intensity. This corresponds to what one would expect *a priori*. Any increase in a country's relative – as compared to its competitors – technological performance will be more rewarding in terms of its relative export performance, or even relative comparative advantage index, in technology-intensive industries than in non-technology-intensive industries (for a discussion of the classification of the various industries in the two groups, see Chapter 3). With respect to the industries with relatively low and/or non-significant technology elasticities, one could argue that basic technology has been essentially diffused,[37] and that the patents relate primarily to less 'important' improvement innovations.

Third, it could be argued that the relatively good results for some of the 'miscellaneous' industries illustrate the crucial impact of industrial innovation on trade performance in some of these highly heterogeneous and ill-defined 'other' industries, where new products and industries eventually emerge.

Technology gaps and wage gaps

Introducing a more comprehensive specification of the set of sector-specific absolute advantages and the inclusion of a proxy for wage costs has its statistical price: we have comparable sectoral wage data for only fourteen OECD countries. The general form of the tests will be:

$$X_{ij} = f(T_{ij}, C_{ij})$$

As above, one of the proxies for the set of technology-related variables, will consist of numbers of patents granted in the United States. However, we will extend the model in order to take into account other sources of absolute advantages (i.e. different degrees of mechanisation and/or, more generally, productive efficiency, expressed by different sectoral capital/labour ratios and/or labour productivities) and in order to explore at a more detailed level the relationship between cost-based processes of adjustment and absolute advantages.[38]

The dependent variable is, as already discussed above, an absolute measure of competitiveness, i.e. independent of the competitiveness of other sectors within the same country. *A priori*, one could have chosen export shares on the world market (as in equation (6.12)) or exports per capita. The drawback of the former measure is that it depends very much on the sheer size of each country, and thus requires a size-proxy on the right-hand side of the estimating equation. Exports per capita, on the other hand, eliminate the direct country size effect, but do not eliminate the possible effect that size might have on a country's export propensity: high for small, and low for large countries. Throughout the estimates that follow, the dependent variable will be the exports of country j in sector i normalised by the population of country j (XPC_{ij}).[39] The innovativeness proxy is again the cumulated 1963–77 number of patents registered in the United States in sector i by country j, but normalised by the population of j (PPC_{ij}). The degree of mechanisation of production (K_{ij}), was approximated by the two-year average of the fixed investment/labour ratio;[40] labour productivity (Q_{ij}/L_{ij}) by the two-year average of the value-added/employment ratio; and the capital/output ratio (I_{ij}) by the two-year average of the fixed investment/value-added ratio, all at current prices and exchange rates. Finally, the proxy for wage costs consisted of the two-year average of the remuneration per employee (R_{ij}) or the two-year average of the ratio of employees' remuneration to value-added (VLC_{ij}).[41]

The following equations were estimated:

$$\ln XPC_{ij} = \beta_{0i} + \beta_{1i} \ln PPC_{ij} + \beta_{2i} \ln ULC_{ij} \qquad \textbf{(6.16)}$$

$$\ln XPC_{ij} = \beta_{0i} + \beta_{1i} \ln PPC_{ij} + \beta_{2i} \ln R_{ij} + \beta_{3i} \ln K_{ij} \qquad \textbf{(6.17)}$$

$$\ln XPC_{ij} = \beta_{0i} + \beta_{1i} \ln \pi_{ij} + \beta_{2i} \ln R_{ij} \qquad \textbf{(6.18)}$$

$$\ln XPC_{ij} = \beta_{0i} + \beta_{1i} \ln PPC_{ij} + \beta_{2i} \ln K_{ij} + \beta_{3i} \ln VLC_{ij} \qquad \textbf{(6.19)}$$

$$\ln XPC_{ij} = \beta_{0i} + \beta_{1i} \ln PPC_{ij} + \beta_{2i} \ln I_{ij} + \beta_{3i} \ln VLC_{ij} \qquad \textbf{(6.20)}$$

$$\ln XPC_{ij} = \beta_{0i} + \beta_{1i} \ln PPC_{ij} + \beta_{2i} \ln I_{ij} + \beta_{3i} \ln K_{ij} \qquad \textbf{(6.21)}$$

Single regression tests of the dependent variable ($\ln XPC_{ij}$) against each of the independent variables were also carried out. Table 6.3 presents the results of the estimates obtained from equation (6.19). Table 6.4, on the other hand, presents a summary of all the results obtained from equations (6.16)–(6.21) as well as from the single regressions.

A first outcome is the corroboration of the importance of the innovativeness variable in the majority of sectors and a demonstration of its robustness. In view of the different functional form of the dependent variable (in per capita terms) and the exclusion of some of the very small or less developed OECD countries (such as Iceland, Greece,

Table 6.3 Export performance, technological levels, degrees of mechanisation of production, wage-costs; regression analysis, forty sectors, log-linear estimates

Sector	Constant	Patents per head	Investment per employee	Wages on value added	$\bar{R}^2$	F
1. Food products	−4.355 (−2.407)**	−0.080 (−0.247)	1.231 (2.359)**	−0.021 (−0.029)	0.403	2.02
2. Textile products	−3.870 (−2.436)***	0.038 (0.246)	0.321 (0.586)	−1.944 (−0.995)	0.204	0.77
3. Industrial inorganic chemicals	−3.397 (−2.965)***	0.505 (4.642)****	0.900 (1.893)**	0.654 (1.091)	0.709	7.29
4. Industrial organic chemicals	−1.879 (−1.921)**	0.818 (5.644)****	0.683 (1.585)*	0.606 (1.168)	0.789	11.24
5. Plastics & synthetic resins	−2.990 (−2.354)***	0.429 (4.776)****	1.488 (2.990)	0.790 (0.773)	0.847	16.67
6. Agricultural chemicals	−5.610 (−0.620)	0.300 (0.279)	0.721 (0.284)	0.198 (0.085)	0.047	0.15
7. Soaps, detergents cleaning & toilet preparations	−0.019 (−0.013)	0.565 (4.389)****	0.027 (0.067)	2.122 (2.965)***	0.762	9.61
8. Paints, varnishes lacquers & allied products	−3.616 (−1.791)*	0.199 (0.957)	0.426 (0.861)	1.244 (1.156)	0.265	1.08
9. Misc. chemicals	−1.482 (−1.294)	0.486 (4.188)****	0.354 (0.717)	1.353 (1.997)**	0.752	9.10
10. Drugs	−0.102 (−0.102)	0.753 (5.006)****	0.362 (0.947)	1.781 (2.862)****	0.776	10.41
11. Petroleum, natural gas, petroleum refining	−2.099 (−0.590)	0.341 (0.702)	0.360 (0.233)	0.345 (0.398)	0.079	0.26
12. Rubber & misc. plastic products	−4.050 (−2.446)***	0.160 (1.119)	1.265 (1.727)*	0.453 (0.305)	0.751	9.04

Continued

Table 6.3 (*Continued*)

Sector	Constant	Patents per head	Investment per employee	Wages on value added	$\bar{R}^2$	F
13. Stone, clay & glass	−3.630	0.131	0.649	0.511	0.316	1.39
	(−1.710)	(0.905)	(1.100)	(0.245)		
14. Ferrous metals	−0.344	0.421	−0.087	0.287	0.437	2.33
	(−0.176)	(2.009)**	(−0.089)	(0.313)		
15. Non-ferrous metals	−0.835	0.507	0.752	1.084	0.590	4.32
	(−0.338)	(2.332)***	(0.859)	(0.694)		
16. Fabricated metal products	−2.426	0.227	0.697	0.463	0.760	9.50
	(−4.639)****	(3.539)****	(2.358)***	(0.773)		
17. Engines & turbines	−3.311	0.409	0.741	−0.466	0.984	180.13
	(−7.275)****	(9.062)****	(3.976)****	(−1.651)*		
18. Farm & garden machinery & equipment	−4.044	0.409	0.933	−1.027	0.733	8.24
	(−2.024)**	(2.013)**	(1.083)	(−0.721)		
19. Construction, mining, material handling machinery	−3.732	0.175	0.911	−1.185	0.913	32.42
	(−5.904)****	(2.010)**	(1.940)**	(−2.815)***		
20. Metal working machinery	−3.689	0.347	0.202	−1.688	0.596	4.43
	(−3.096)****	(1.607)*	(0.356)	(−1.315)		
21. Office, computing & accounting machinery	−2.187	0.354	−0.195	0.254	0.585	4.22
	(−1.837)**	(2.472)***	(−0.533)	(0.456)		
22. Special industrial machinery	−2.104	0.466	0.270	−0.394	0.866	19.33
	(−2.369)***	(3.518)****	(0.988)	(−0.479)		
23. General industrial machinery	−4.342	0.205	1.317	−1.324	0.935	43.43
	(−7.004)****	(2.380)***	(2.733)***	(−2.662)**		
24. Refrigeration & service machinery	0.304	1.235	−0.447	2.291	0.591	4.34
	(0.087)	(2.865)***	(−0.628)	(0.592)		
25. Misc. (non-electrical) machinery	−7.235	0.121	2.946	−0.445	0.871	20.32
	(−4.676)****	(0.649)	(3.617)****	(−0.482)		
26. Electrical transmission & distribution equip.	−2.203	0.342	−0.049	0.475	0.615	4.79
	(−1.455)	(2.545)****	(−0.133)	(0.222)		
27. Electrical industrial apparatus	−2.030	0.351	0.015	0.777	0.722	7.81
	(−1.827)**	(3.494)****	(0.053)	(0.485)		
28. Household appliances	−1.252	0.556	0.311	0.728	0.765	9.75
	(−1.502)	(5.365)****	(0.692)	(0.711)		
29. Electrical lighting & wiring equipment	−2.408	0.380	−0.093	2.645	0.610	4.70
	(−2.473)***	(3.048)****	(−0.174)	(2.250)***		
30. Misc. electrical equipment	−2.675	0.427	0.165	0.999	0.764	9.71
	(−3.791)****	(4.966)****	(0.625)	(1.475)		
31. Radio & TV receiving equipment	−3.726	0.151	0.270	0.189	0.117	0.40
	(−1.785)*	(0.731)	(0.285)	(0.105)		
32. Electronic components & communication equip.	−2.389	0.272	0.205	0.764	0.699	6.97
	(−2.955)***	(3.305)****	(0.442)	(0.928)		
33. Motor vehicles & parts	−2.810	0.345	0.498	−1.825	0.638	5.29
	(−1.290)	(1.467)	(0.567)	(−1.191)		
34. Ships & boats	−3.119	0.243	1.784	−1.362	0.288	1.21
	(−1.556)*	(0.928)	(1.230)	(−0.639)		
35. Railroad equipment	−3.893	0.458	0.160	−0.449	0.667	6.00
	(−4.373)****	(3.204)****	(0.859)	(−0.405)		
36. Motorcycles, bicycles	−4.221	0.196	0.086	0.610	0.076	0.25
	(−1.169)	(0.587)	(0.045)	(0.254)		
37. Misc. transport equipment	−3.228	0.672	0.465	−0.661	0.424	2.21
	(−0.871)	(1.358)	(0.580)	(−0.240)		
38. Missiles, space vehicles, ordnance	−0.517	0.756	−0.391	3.350	0.311	1.35
	(−0.177)	(1.951)**	(−0.447)	(1.222)		
39. Aircraft & parts	0.030	0.915	−1.101	0.077	0.582	4.18
	(0.012)	(2.622)***	(−2.425)***	(0.029)		
40. Professional & Scientific instr.	−2.377	0.415	−0.533	−0.516	0.725	7.90
	(−3.303)****	(4.073)***	(−1.037)	(−0.861)		

Technological levels approximated by patents per head.
t-Statistics in parentheses. **** significant at the 1% level; *** at the 5% level; ** at the 10% level; * at the 15% level.

Table 6.4 A tentative taxonomy of the factors affecting export performance, by sector

(1) Sector	(2) Technological innovativeness as expressed by patenting	(3a) Process-related technological advantages as expressed by labour productivity	and/ or by	(3b) degree of mechanisation of production (capital/ labour ratios)	(4) Cost-based competitiveness	(5) Other factors not identified by the model
1. Food products		X		X		
2. Textile products						*
3. Industrial inorganic chemicals	X	X				
4. Industrial organic chemicals	XX					
5. Plastics and synthetic resins	X	X		X		
6. Agricultural chemicals						*
7. Soaps, detergents, cleaning and toilet preparations	XX				(a)	
8. Paints, varnishes, lacquers and allied products						*
9. Miscellaneous chemicals	XX				(a)	
10. Drugs	XX				(a)	
11. Petroleum, natural gas, refining						*
12. Rubber and miscellaneous plastic products	X	X		X		
13. Stone, clay and glass		X				*
14. Ferrous metals	X					*
15. Non-ferrous metals	X	X				
16. Fabricated metal products	XX	X		XX		
17. Engines and turbines	XX	X		X		
18. Farm and garden machinery and equipment	X	XX				
19. Construction, mining, material handling machinery	XX	X		X	X	
20. Metal working machinery	XX				X	
21. Office, computing and accounting machinery	XX	X				
22. Special industrial machinery	XX	X				
23. General industrial machinery	XX	X		X	X	
24. Refrigeration and service machinery	X	X				
25. Miscellaneous (non-electrical) machinery	X	X		XX		
26. Electrical transmission and distribution equipment	XX				X	
27. Electrical industrial apparatus	XX	X			X	
28. Household appliances	XX	X				
29. Electrical lighting and wiring equipment	X	X			(a)	
30. Miscellaneous electrical equipment	X	X				
31. Radio and television receiving equipment						*
32. Electronic components and communication equipment	XX	X				
33. Motor vehicles and parts	X	X		X	X	
34. Ships and boats	X	X				*

Continued

Table 6.4 *(Continued)*

(1) Sector	(2) Technological innovativeness as expressed by patenting	(3a) Process-related technological advantages as expressed by labour productivity	and/ or by	(3b) degree of mechanisation of production (capital/ labour ratios)	(4) Cost-based competitiveness	(5) Other factors not identified by the model
35. Railway equipment	XX	X			X	
36. Motorcycles, bicycles		X				*
37. Miscellaneous transport equipment	X	XX		X	X	
38. Missiles, space vehicles, ordnance	XX	(a)			X	
39. Aircraft and parts	X			(a)		
40. Professional and scientific instruments	XX	X			X	

The following conventions have been adopted:
X: The variable is significant (at 10% or more) in at least one regression estimate.
XX: 'dominant variable'. It always appears significant (at 15% or more) in all attempted estimates; whenever introduced alone as an independent variable yields an R^2 (adjusted for the degrees of freedom) higher than 0.30; there is at least one estimate where it is significant at 1% level.
*: None of the estimates yield an R^2 (adjusted for the degrees of freedom) higher than 0.50.
(a): The variable is significant at least once but the sign is opposite to that predicted.

Column (4) refers to the ratio of employee remuneration to value added and/or to remuneration per employee with a negative and significant value. Note that in sector 37 it is remuneration-to-value-added which appears significantly negative in one estimate, while remuneration-per-employee is significantly positive in another one.

Ireland, Turkey, etc.) from the sample in Table 6.3, this feature is certainly worth observing.[42] Compared to Table 6.1, the results obtained for the innovativeness variable in Table 6.3 illustrate that in the majority of cases (thirty-four out of forty), the results are indeed stable: the patent variable is either non-significant or significant in both estimates.[43] In only three cases does a previously significant estimate become insignificant (rubber and plastic miscellaneous products, miscellaneous non-electrical machinery, and motor vehicles and parts), while in three other cases (industrial organic chemicals, miscellaneous chemicals, railway equipment) the opposite occurs.

Furthermore, the results presented in Tables 6.3 and 6.4 highlight the significance of the technology variable in a number of sectors: in chemical sectors characterised by relatively high degrees of process and product innovation such as organic chemicals, detergents, miscellaneous chemicals and, even more so, pharmaceuticals; in mechanical engineering, in practically all sectors (machine tools, special and general industrial machinery, construction and mining machinery, engines and turbines); and in the majority of electrical/electronic sectors with a significant rate of technological innovation (electronic components and communication equipment, office and computing machinery, electrical industrial apparatus, professional and scientific instruments, space and missile equipment).

The picture is less clear with respect to the sectors producing consumer durables and various kinds of transport equipment. Many of these sectors belong to what we referred to as scale-intensive sectors. As we discussed at greater length in Chapter 4, these sectors are, generally speaking, characterised by international oligopolistic structures, reflecting the adoption of innovations produced in other sectors and embodied in capital equipment; mass production and various kinds of economies of scale; the successful management of complex production systems; and product design and performance, all of which are not fully patented. One should not therefore be surprised to find, in some of these sectors, that the technology proxy used does not capture the full complexity of the innovative process.[44]

It is difficult to separate the effects of innovativeness, strictly defined, from labour productivity and the degree of mechanisation. As already discussed in Chapter 5, these variables are all correlated through 'virtuous circles' of innovation, capital accumulation, the adoption of best-practice equipment, etc. Table 6.3 only presents results for the mechanisation variable, while Table 6.4 also provides a summary of some of the other tests. The labour productivity variable results are, by and large, similar to the mechanisation variable results.[45]

Overall, labour productivity and mechanisation/automation of production appear to be relatively important within the mechanical engineering group and appear to be broadly complementary to straightforward innovativeness (as measured by patents) in several scale intensive sectors (e.g. in miscellaneous transport equipment, farm and garden machinery) and in one supplier-dominated sector (fabricated metal products), where one would expect technical progress to be embodied in equipment and machines. Generally, labour productivity, capital/labour ratios, or both, appear to be important in sectors which are strongly affected by innovations acquired through input–output flows instead of, or in addition to, own internally produced innovations.

The long-term complementarity of these two processes of technological change is obvious: straightforward innovativeness, equipment-related technological advances, increasing degrees of mechanisation/automation of production are all factors which determine absolute advantages of some countries vis-à-vis others in that they yield better products and/or univocally superior techniques of production.

In relation to these technology gaps, we must also assess the role of the wage-related variable. We have already argued above that in a world generally characterised by non-decreasing returns and freely reproducible capital and intermediate inputs, the greatest source of international variance in input prices is likely to be the international difference in wage rates. The proxy for unit wage costs used in Table 6.3 is the wages to value-added ratio. The results presented in Tables 6.3 and 6.4 suggest that the cost-related variable used here performs rather poorly, and is more often than not the opposite sign to what one would expect (i.e. positive).

A possible explanation for the positive sign is that the wage variable stands for different degrees of skill of the labour force. However, this cannot be the only explanation; a closer look at the results shows that the coefficient is negative precisely in those sectors where we would expect labour-embodied skills to be of crucial importance (such as in the machinery sectors), whereas positive, significant results are obtained for two process industries (soap and detergents and miscellaneous chemicals) where it could be considered of less importance.

Despite the empirical and statistical shortcomings of the above tests, the results presented in Tables 6.1, 6.3 and 6.4 provide support for the hypothesis of the dominance of univocal technology advantages over cost-related factors in shaping international competitiveness: in a good number of sectors, the international composition of trade (within each sector) is explained by the sector-specific patterns of technology gaps/leads, and in particular by different degrees of innovativeness. This holds even when we introduce into the estimate a proxy for wage cost-related factors.

Before proceeding to a dynamic analysis of absolute advantages and relative costs, it is worth mentioning the role of the capital/output ratios in the explanation of export flows. The proxy for the possible bias in capital use does not show any evident correlation with export performance, either if used alone or in conjunction with our technology gap and cost variables.[46] In other words, the tests do not appear to conflict with our hypothesis that technological advantages are associated with a more efficient use of both labour and capital which dominates over static interfactoral substitution,[47] irrespective of the capital intensity of the sectors.

6.4 The dynamics of international technological advantage and competitiveness

Technological innovation creates technology gaps and is a fundamental source of absolute advantages/disadvantages between countries. Conversely, international technological diffusion tends to reduce technological gaps. Here, we are interested in how changing patterns of competitiveness depend on the overall balance between the two processes, and on their relation with the trend in unit labour costs. In a hypothetical world tending to technological convergence, intracountry mechanisms of specialisation (related to relative prices, income distribution and, ultimately, comparative advantages) are likely to become the fundamental factor in explaining patterns of international competitiveness and the world distribution of exports within each sector. The opposite will apply to a world where technological asymmetries are increasing: technological gaps between countries within each sector would become the major determinant of international market shares.

We have attempted in the above to illustrate the dominant role of technological advantages in a 'static' cross-country analysis of international competitiveness. We will now look more closely at the dynamic aspects of such competitiveness patterns. The results presented so far are, by and large, consistent with those findings from time-series estimates of cost or price elasticities of exports showing an unexplained trend[48] or even a long-term 'perverse' relationship between the evolution of cost advantages and export market shares. The latter finding is sometimes referred to as the 'Kaldor paradox',[49] whereby countries which improved their export performance the most are also found to be those countries whose cost-related competitiveness deteriorated the most and vice versa.

Some evidence on the trends in exports, innovativeness and costs

It is not possible, because of the lack of the appropriate data on productivity and wages, to test the dynamic version of the model presented above at the level of sectoral disaggregation used so far. We will confine our analysis here to rates of change in the manufacturing sector as a whole.

At this level of aggregation, the performance indicator (rates of change in exports) is inevitably the outcome both of changing country-wide absolute advantages and changing patterns of specialisation. However, we can still explore the relative importance of average absolute technological advantage as compared to cost-related changes in competitiveness.

Table 6.5 shows some estimates of the relationship between changes in competitiveness, costs and technological indicators (innovativeness – measured by patenting – and labour productivity).

A comparison between the estimate under 1 and the estimates under 2 and 4 broadly corroborate the previous hypothesis of the dominance of the trends in technological asymmetries over cost-related factors as determinants of trade flows. Over the longer period (1964–80), unit labour costs generally acquire the correct negative sign, but the values are statistically insignificant. Relative trends in technological innovativeness, on the other hand, differ substantially from these trends in unit labour costs, and explain a good part of export changes. In other words, in the long term, unit labour costs adjust to the underlying trends in innovativeness and productivity, but play a relatively small role in determining long-term trade performance.

It should be stressed that here we are considering costs expressed in international currency (dollars): in the relationship between international technological asymmetries, levels of domestic absorption, domestic income distribution and exchange rates, the latter will adjust costs in dollars near those levels consistent in the long run with the changing pattern of international technology gaps.

Certainly, our variables do not capture the entire set of factors affecting trade. In particular, the innovativeness variable used here may not be entirely adequate to represent the process of technological innovation and international diffusion of technology when these do not involve patented innovations; we do not have any variable representing the changing average degree of participation of each national industry to the international oligopolies, inward and outward flows of international investment, changing domestic structures of supply, and so on;[50] and our estimates do not include any proxy for the quality – in terms

of income elasticities – of the sectoral patterns of export specialisation of each country (see the section on patterns of demand and trade on p. 164).

Bearing these limitations in mind, the reader may appreciate the powerful impact of the changes in the technology variables, either expressed by patenting or by a variable highly correlated with it, namely labour productivity (cf. estimate 3) on trade performance.

Similar to the trends in productivity (cf. Chapter 5 above), a 'catching-up effect' has been at work, so that countries with relatively low levels of wages have been able, other things being equal, to enjoy a somewhat higher growth in exports (see estimate 6).[51] Our interpretation of this phenomenon is that, since the Second World War, processes of technological diffusion have outpaced the domestic growth of wages, thus creating a 'buffer of competitiveness' which has allowed high rates of growth of exports in most OECD countries which were catching up with the United States and started from relatively low wage levels. Conversely, in the most recent period, the 'catching-up effect' appears to have faded away within the group of fully industrialised OECD countries to which our tests refer (cf. the period 1970–80 in estimate 3).[52]

The importance of the technological factors appears also in relation to the trends in trade balances (approximated here by the growth in exports minus the growth in imports), although with less force (compare estimates 8 and 9 with 4–6).

As already mentioned, the goodness of fit of our estimates decreases considerably when the sub-period 1970–80 is examined alone. Our own hypothesis – which cannot be tested adequately here – is, that this has not been the result of the decreasing importance of the role of innovativeness and technology in international competitiveness, but primarily the result of changing macroeconomic policies. Exchange rates in the 1970s have been heavily managed from a perspective other than trade policy, including the control of domestic inflation. In a sense, this might have led to 'disequilibrium' values in the long-term relationship between technological asymmetries, wage-costs and exchange rates, since the various countries have shown widely differing emphasis upon the objectives of growth, and of the control of inflation.[53] Two countries in particular are 'out of line' in the estimated functions, namely the United States and the United Kingdom. As regards the latter, the 1980 exports might not yet fully account for the full impact of a revalued pound. In general, the shorter period of the 1970s is likely to be more sensitive to 'disequilibria' in the international market produced by discrete jumps in the exchange rates which take time to be fully accounted for in terms of trade flows.[54]

Table 6.5 The determinants of trade competitiveness, aggregate manufacturing, regression analysis, 1964–80 and 1970–80

Dependent Variable		Period	Constant	ULC	RPAT	RWAGE	LW	PH	$\bar{R}^2$	F	Form of the Estimate
EXP	1.	64–80	12.078 (2.268)***	−0.064 (−0.043)					0.002	0.02	lin
		70–80	3.828 (3.080)***	0.590 (1.297)					0.063	1.68	lin
EXP	2.	64–80	8.924 (14.471)****		1.230 (6.710)****				0.815	45.03	lin
		70–80	4.255 (7.853)****		1.023 (2.312)***				0.303	5.35	lin
EXP	3.	64–80	2.945 (1.350)			0.029 (0.981)		3.520 (4.010)****	0.624	9.31	lin
		70–80	2.150 (1.543)			0.163 (0.616)		1.556 (1.175)	0.355	3.76	lin
EXP	4.	64–80	2.240 (11.884)****	−0.028 (−0.184)	0.376 (6.396)****				0.796	20.65	log
		70–80	1.301 (7.035)****	3.445 (2.003)**	0.233 (2.003)**				0.375	4.00	log
EXP	5.	64–80	8.512 (3.593)****	0.116 (0.181)	1.231 (6.341)****				0.793	20.11	lin
		70–80	2.411 (2.253)***	0.607 (1.923)**	1.081 (2.777)***				0.464	5.32	lin
	6.	64–80	15.609 (3.805)****	−0.919 (−1.214)	0.938 (4.220)****		−0.018 (−1.989)**		0.849	19.68	lin
		70–80	4.102 (1.632)	0.355 (0.757)	0.811 (1.503)*		−0.002 (−0.748)		0.432	3.54	lin
BAL	7.	64–80	0.496 (0.089)	−0.252 (−1.630)*					0.108	0.03	lin
		70–80	1.245 (0.945)	−0.476 (−1.080)					0.016	1.17	lin
BAL	8.	64–80	−2.297 (−1.769)*		0.800 (2.073)**				0.248	4.30	lin
		70–80	−1.440 (−2.710)***		1.144 (2.636)***				0.373	6.95	lin
BAL	9.	64–80	−1.817 (−0.364)	−0.135 (−0.600)	0.798 (1.950)**				0.155	1.92	lin
		70–80	−0.203 (−0.174)	1.407 (1.177)	1.105 (2.593)***				0.399	4.31	lin

**** significant at the 1% level; *** at the 5% level; ** at the 10% level; * at the 15% level.

Variables:

EXP = percentage change in exports (current values in $).
BAL = percentage change in exports minus percentage change in imports.
ULC = percentage change in unit labour costs at current exchange rates (wage rates in international currency divided by labour productivity at constant prices and exchange rates).
RPAT = percentage change in the number of patents registered in the USA.
RWAGE = percentage change in hourly worker remuneration, (in $).
LW = levels of hourly workers remuneration at the initial year.
PH = percentage change in hourly labour productivity (output per manhour at constant prices).

The 11 countries of the estimates are the same as in Table 3.6.

Sources: Elaborations on unpublished data from the US Bureau of Labor Statistics, Confederation of Swedish Industries and national sources.

6.5 Conclusions

In this chapter we have analysed the relationship between technological gaps/leads and international competitiveness and their implications. Processes of 'circular causation' are particularly difficult to disentangle and our attempt has to be considered as a tentative exploration. However, despite the statistical and data difficulties, the results obtained are consistent with the proposed model: technological gaps, in terms of asymmetries in the techniques of production and product-technologies, are the dominant feature of an international economic system characterised by technological learning, innovation and imitation along technological trajectories of progress that continuously bring about a more efficient use of both labour and capital, and add new or improved products to production baskets.

A first consequence is that the international composition of trade flows is primarily explained by the pattern of technological lags and leads. The latter, we argued, broadly correspond to Ricardian absolute advantages. On the grounds of these absolute advantages, cost-related adjustments will undoubtedly take place: each country gains a relative specialisation in those sectors which, given the patterns of costs and income distribution, yield relatively higher profitabilities.

However, as we discussed in Chapter 5, the intranational intersectoral differences in comparative advantages are generally much smaller than international gaps in technology: in terms of our model, this implies that the boundaries within which 'Ricardian' processes of adjustment take place (i.e. processes of intersectoral allocation through relative prices and relative profitabilities) are rather tight. The model developed in this chapter predicts that in these circumstances the main adjustment mechanism in the international markets will run from sectoral (and country-wide) technological gaps/leads to sectoral (and country-wide) market shares in world exports. This interpretation allows a clear and, we would claim, rigorous distinction between three different concepts: 'competitiveness', 'comparative advantage', and 'relative specialisation'.

'Competitiveness' is an 'absolute' concept, in the sense that it is independent of intranational comparison of the activities in which a country is 'better' or 'worse', although it obviously compares one country with the rest of the world. In the model developed here, the various degrees of national competitiveness are the outcome of an adjustment mechanism linking absolute advantages and market shares (and, through that, domestic rates of activity, incomes and wages). Conversely, 'comparative advantage' relates, as is common in trade theory,

to relative efficiencies: that is, to the intersectoral, intranational comparison of technological lags/leads. These comparative advantages lead to a 'Ricardian' adjustment process, based on intersectoral differences in profitabilities.

Finally, relative specialisation is in a sense the revealed outcome of both market-shares adjustments and Ricardian adjustments. In the simplest case, where no interdependencies between technologies and sectors exist, relative specialisation mirrors comparative advantage. In the more complex and realistic case, when some absolute advantages/disadvantages act as externalities and semi-public goods, absolute advantages will shape the intersectoral allocations of exports in ways which are likely to show only indirect links with comparative advantages, as shown by MacDonald and Markusen (1985).

Notwithstanding the difficulty in finding adequate indicators of the factors underlying both absolute and comparative advantages, the evidence presented here is consistent with the hypothesis that absolute advantages are a dominant factor in explaining trade flows. A similar concept of 'dominance' applies to the dynamic relation between the technological innovativeness of each country as a whole and relative costs: the trends in the former appear to have a much greater impact than changes in the latter as determinants of long-term variations in the competitive position of each country. The paradox pointed out by Kaldor who showed the worsening trade performance of countries whose 'competitiveness' in terms of costs was improving, is confirmed here and in some sense explained: the long-term trends in trade performance of each economy are essentially determined by their different degrees of innovativeness and technological dynamism.

These results can be easily linked with the analysis of the effect upon international competitiveness of the level and changes in the patterns of specialisation, in terms of the income elasticities of exports, i.e. the 'structural gaps' discussed in Section 2 of this chapter (see also Lafay, 1981; CEPII, 1983; Rothschild, 1985).[55] The importance of both technology gaps and demand-related gaps highlights the fundamental role of structural factors (that is, factors related to the long-term characteristics of the pattern of technological and capital accumulation) which shape the varying levels of adaptation of each country to the world economy, and, thus, also their differing degrees of success in terms of market shares, growth possibilities (consistent with the foreign balance constraint) and wage growth. In the next chapter we attempt to draw these strings of the analysis together, with the help of a simple formalised model showing the relationship between technology, demand elasticities of export and growth.

Appendix

A methodological note

The data on investment, productivity, employees' remuneration, etc., used in Tables 6.1 to 6.4 are based on unpublished OECD data for sixty-six manufacturing sectors at 2-, 3-, 4-digits of the ISIC classification-level, supplemented by the *UN Yearbook of Industrial Statistics* and national sources. Export data are from the OECD, *Trade by Commodities*, various years.

The 'innovativeness' variable is approximated by the number of patents registered by each country in the United States in each of the forty sectors considered. These sectors have been built around OTAF attributions of patents to SIC classes. The concordance between patent (SIC) classes and trade (SITC) classes is described in Soete (1981a). At this level of aggregation, there is no strict correspondence between these forty sectors and the various industrial performance indicators (such as investments, productivity, employees' remuneration, etc.) expressed in the ISIC categories at the disaggregation allowed by OECD data and/or national sources. Thus, we are sometimes forced to attribute to any one of the forty sectors a performance indicator belonging to an ISIC class of which the former is a sub-set. Moreover, quite a few countries had gaps in their data. We therefore assumed that the relative values of the relevant ratios (e.g. value added per employee, investment per employee, etc.) compared to a reference country (e.g. the United States) was the same in the missing sector as for the more aggregate sector for which the data were available.

Table 6A.1 shows the correlation matrix of the independent variables of estimates 6.12–6.15.

As mentioned in the text, the 'capital' variables of the estimates 6.14 to 6.19 have been approximated by two-year (1977–8) averages in the ratio of gross fixed investment to total employment (K_{ij}) and to value added (I_{ij}), at current prices and exchange rates. Similarly, labour productivity is approximated by the two-year (1977–8) ratio of value added to employment.

The two capital proxies are certainly far from perfect. As we briefly discuss in Dosi (1984), the investment/value-added ratio (I_{ij}/Y_{ij}) is linked to the 'true' capital/value-added ratio (K_{ij}/Y_{ij}) by the formula:

$$I_{ij}/Y_{ij} = [\sigma_1(g_{ij}) + \sigma_2(a_{ij})](K_{ij}/Y_{ij}) \tag{A6.1}$$

where g_{ij} is the sectoral rate of growth and a_{ij} is the rate of scrapping. Similarly, the investment/employment ratio (I_{ij}/N_{ij}) is linked to the

Table 6A.1 Correlation matrix of the independent variables

	ln Pop	ln GDP	ln KL	ln RDSH[b]	Dist
ln Pop	1.00				
ln GDP	0.90	1.00			
ln KL	−0.17	0.21	1.00		
ln RDSH	0.60	0.87	0.57	1.00	
ln Dist	−0.15	−0.04	0.25	0.14	1.00
ln PSHA[a] $i=$ 1	0.48	0.77	0.60	0.94	0.18
2	0.51	0.79	0.60	0.96	0.23
3	0.55	0.82	0.62	0.90	0.26
4	0.54	0.80	0.54	0.90	0.22
5	0.56	0.81	0.58	0.93	0.30
6	0.53	0.78	0.53	0.94	0.25
7	0.54	0.77	0.48	0.88	0.24
8	0.68	0.83	0.39	0.88	0.15
9	0.53	0.79	0.58	0.88	0.20
10	0.55	0.80	0.49	0.92	0.23
11	0.69	0.88	0.41	0.89	0.14
12	0.43	0.76	0.71	0.92	0.16
13	0.46	0.77	0.68	0.92	0.11
14	0.52	0.81	0.65	0.91	0.12
15	0.54	0.82	0.62	0.88	0.15
16	0.38	0.72	0.74	0.91	0.15
17	0.63	0.86	0.53	0.92	0.16
18	0.38	0.72	0.73	0.91	0.15
19	0.40	0.73	0.74	0.91	0.17
20	0.50	0.81	0.65	0.95	0.15
21	0.46	0.76	0.67	0.96	0.18
22	0.40	0.73	0.72	0.90	0.20
23	0.39	0.71	0.70	0.93	0.18
24	0.47	0.76	0.60	0.94	0.20
25	0.46	0.78	0.67	0.96	0.16
26	0.51	0.81	0.65	0.95	0.17
27	0.53	0.81	0.62	0.90	0.28
28	0.47	0.78	0.66	0.96	0.16
29	0.60	0.87	0.59	0.94	0.22
30	0.55	0.82	0.59	0.93	0.21
31	0.59	0.86	0.58	0.96	0.20
32	0.48	0.79	0.69	0.93	0.21
33	0.51	0.80	0.63	0.93	0.14
34	0.53	0.79	0.60	0.89	−0.01
35	0.63	0.85	0.43	0.94	0.12
36	0.67	0.83	0.32	0.90	0.10
37	0.61	0.83	0.46	0.94	0.13
38	0.59	0.83	0.48	0.93	0.13
39	0.58	0.82	0.51	0.93	0.14
40	0.42	0.75	0.72	0.93	0.18

[a] *i* are the industries identified in SIC-terms and listed from 1 to 40 in Table 6.3.
[b] RDSH stands for the share of country *j* R&D expenditures (BERD) in total OECD R&D expenditures (BERD).

Source: Soete (1980).

'true' degrees of mechanisation of production (K_{ij}/N_{ij}) by

$$I_{ij}/N_{ij} = [\sigma_1(g_{ij}) + \sigma_2(a_{ij})]\,(K_{ij}/N_{ij}) \qquad \textbf{(A6.2)}$$

For the purposes of our tests, however, our proxies keep an economic meaning. More specifically, I_{ij}/Y_{ij} is used to test whether there is a significant effect of 'static substitution' (of the production function type). We know that international differences in labour productivities are quite high (cf. Chapter 3): were they essentially explained by movements along the same production functions, the variance in (K_{ij}/Y_{ij}) should be high enough to dominate statistically over the 'noise' introduced by the variance associated with internationally different rates of growth of output and rates of scrapping. A similar argument applies to the use of (I_{ij}/N_{ij}). A more general discussion of the meaning of capital/labour ratios in dynamic economies – whose conclusions we broadly share – is given in Pasinetti (1981).

Notes

1. We also assume constant returns to scale and the absence of any variable input other than labour.
2. For more detail, see Chapter 7.
3. See Pasinetti (1981) whose model of economic growth embodies a similar link between wage rates and average technological levels of each economy.
4. This argument is consistent with Pasinetti's account of the relationship between structural change and international trade (cf. Pasinetti, 1981).
5. For somewhat similar Ricardian analyses, see Dornbush, Fisher and Samuelson (1977), Henner (1983, 1984), Wilson (1980). See also Chapter 7.
6. *Ibid.*, p. 291.
7. Obviously, with the exceptions of products linked to the only actual 'endowments' we know of, such as mineral endowments, sunshine, etc.
8. We owe the original definition of 'dominance' in this context to Luigi Orsenigo.
9. The latter hypothesis appears to us more reasonable than the opposite one of full employment.
10. Note that the argument related to a product innovation would be conceptually identical.
11. A similar adjustment process, within a Marxian framework of analysis, is analysed by Shaikh (1980). One might also wonder why in our model, characterised by non-decreasing returns, international adjustments do not lead to total specialisations, but to market sharing. There are four complementary reasons, namely (a) the products of each sector may well be imperfect substitutes of each other in ways which correspond to the different locations of production (see Isard, 1977; Armington, 1969); (b) each sector may be composed of groups of homogeneous products, manufactured with different efficiencies in the different countries (Petri, 1980); (c) the groups of products of each sector may differ in their performance and technological sophistication (Shaked and Sutton, 1984); (d) as we saw, the sectoral technological levels of each country are averages of distributions across different firms, so that there are always likely to be several pairs of products/firms for which the international location of production is indifferent (i.e. these firms, located in different countries and producing an identical product are an 'evolutionary equilibrium').

12. Clearly, for other theoretical purposes, such as the intertemporal analysis of income distribution or of the macroeconomic rates of activity, even small changes in the capital/output ratio are important.
13. See Chapter 4 for some sectoral evidence.
14. Cf. Haitani (1970) and Chapter 3 above.
15. See Chapter 3.
16. One also requires Harrod-neutrality of technology, identical rates of profit, etc.
17. One needs to assume non-decreasing returns and no scarce factor. These are likely to correspond to the normal conditions of developed economic systems (see Chapter 5).
18. See Caves, Porter and Spence (1980), Caves (1985).
19. See Dixit and Norman (1980), Brander (1981) and Krugman (1979a), Helpman (1984a), Eaton and Kierzkowski (1984), and, for a critical survey, Caves (1980).
20. Cf. Glejser, Jacquemin and Petit (1980).
21. See, among others, Grubel and Lloyd (1975), Giersch (1979), Helleiner and Lavergne (1979), Caves (1982) and Helleiner (1981). For a critical overview, cf. Onida (1984).
22. Cf. for example, the analysis by US Tariff Commission (1973).
23. See Nelson and Winter (1982).
24. This view is supported by the findings at firm-level by Lipsey and Weiss (1981), and Lipsey and Kravis (1985), showing a significant complementarity between exports and local production abroad by US firms.
25. A similar point on the sector-specificity of trade analysis is made by Leamer (1974).
26. Cf. Linder (1961), Barker (1977), Vona (1979).
27. In particular, with regard to a group of engineering products, they find rather robust links for the United States, Germany, Netherlands, Denmark, Norway, some (but weak) links for Japan, Italy and Sweden and non-significant/non-existent correlations for the United Kingdom, France and Belgium. Similarly, they identify a few engineering products which, in cross-country analysis, show rather close correlations between national specialisations and 'backward' linkages on the home markets (see Andersen *et al.*, 1981).
28. See the important analyses of Lafay (1981), and CEPII (1983).
29. On this point see Kaldor (1980) and Pasinetti (1981).
30. An interesting model, which is consistent with this proposition, is in Shaked and Sutton (1984): different product qualities are demanded at different income levels while unit variable costs rise with quality but less than proportionally. The model is important also in other respects: it introduces something like a 'hierarchical order' in the patterns of demand and studies market structures stemming from different combinations of demand schedules and production technologies. For a discussion and some evidence on

diverging unit labour costs among OECD countries, see Ghymers (1981).

31. Excluding Iceland, because of lack of export data at the level of disaggregation required for the analysis; and grouping Belgium and Luxembourg.
32. Data on patenting in the United States have been reclassified (here, as well as in the estimates presented earlier on labour productivities – cf. Table 3.5) into US Standard Industrial Classification (SIC) groups by the Office of Technology Assessment and Forecasting (OTAF) of the US Patent and Trademark Office. Standard International Trade Classification (SITC) correspondence problems forced us to group together 'ordnance' and 'guided missiles, space vehicles and parts', reducing the number of sectors to forty. Details concerning SIC-definition, SITC-correspondence and some of the problems involved are given in Soete (1981a).
33. That this is not an indicator of 'revealed endowments' should be clear from our discussion of technical progress in Chapter 5: when 'production functions', so to speak, are different across countries, capital/labour ratios do not reveal anything of the capital intensity of production processes (in terms of output) but simply their degrees of mechanisation.
34. The sample being limited to the OECD countries only. This is to be expected.
35. The complete correlation matrix between the various independent variables is given in Table 6A.1 of the appendix.
36. I.e. the degree to which a notional 1 per cent increase in a country's foreign (US) patent share would lead to an increase in that country's OECD export share.
37. An interesting explanation in terms of the importance of multinational corporations in the export performance of some countries (Belgium, Canada and Ireland in particular), in some of the industries with low technology elasticities shown in Table 6.2 has been suggested by John Dunning. Our patent data do indeed only take into account endogenous technological performance.
38. The results that follow are based on Dosi and Soete (1983).
39. In order to test the stability of the results whenever different size-related propensities to export are accounted for, in some estimates not shown here, we added 'population' to the set of independent variables: the results remained quite stable (in terms of significance, although clearly not in terms of values of the coefficients).
40. For more details on the sources of the variables, see the appendix.
41. The reader should note that the variable falls short of being a unit wage cost measure. It would be so if we had a proper 'physical' productivity measure at the denominator. As we are forced to use value added at current prices and exchange rates, the ratio of wages to value added is a mixed measure of unit wage costs and income distribution. However, it maintains an economic significance, in the sense that processes of adjustment related to relative prices are ultimately based on relative profitabilities. Were technology perfectly neutral (in the Harrod sense), that ratio would be an inverse monotonic function of the profit rates.
42. The only 'low-development' OECD country in the smaller sample is Portugal.
43. Within countries which are well below the technological frontier, one would expect innovativeness, as measured by US patenting, to play a rather minor role and, thus, misrepresent their technological levels.

44. Out of the twenty-three sectors which maintain the significance in both samples, ten decrease their level (on the t-test) and four improve it. The only rather surprising result is the fall in the significance of patenting, from 1 per cent to 15 per cent in the estimates given in Table 6.3. However, this is due to an abnormally high multicollinearity between the three independent variables.
45. Our analysis also excludes several traditional sectors (clothing, footwear, wood products) where patenting is negligible.
46. Note that the degree of multicollinearity between degrees of mechanisation and patenting is, on average, low, while this is not so for patenting and productivity (cf. Chapter 5).
47. Used alone, capital/output ratios are positive and significant (at 5 per cent or 1 per cent level) in only one case, negative and significant in two cases. Whenever used together with patenting and a cost variable they are significant in five cases, three with a positive sign and two with a negative one. Moreover, when net balances are used as dependent variables, capital/output ratios come out significant (at 5 per cent or more), with a negative sign in six cases: if anything, this indirect measure of 'comparative advantage' is sometimes associated with capital-saving technical progress.
48. See, in particular, Fetherson, Moore and Rhodes (1977), Modiano and Onida (1983), and, for an extensive analysis of the estimates of price elasticities, see Stern, Francis and Schumacher (1976).
49. Cf. Kaldor (1978).
50. On the importance of these factors, see Section 6.2 above.
51. Moreover, note that estimate 6 may well underestimate the catching-up factor, in so far as the latter is overlapping with an above-average growth of patented innovations, already accounted for by the RPAT variable.
52. For the list of countries considered in the estimates of Table 6.5, see Table 3.6.
53. In general, the floating exchange rates of the 1970s have been affected by factors different from manufacturing competitiveness, e.g. short-term capital movements due to interest rate differences, changes in oil prices, etc.
54. Notably, the sensitivity of the estimates is very low if the initial or final year is changed over the period 1964–80. The opposite applies to the 1970s taken alone.
55. Rothschild (1985) shows that a 'catching-up' effect has also been at work through the 1960s and 1970s in terms of export composition, and that this has had a relevant effect upon differential income growth of the European OECD countries. The data on which the calculations are based, however, are rather aggregate and approximate income elasticities with percentage growth of world exports.

    In the more complex analysis by Lafay (1981), the conclusions on 'catching-up' are less straightforward. However, the main point holds: differences in the patterns of specialisation according to their demand dynamism are a crucial ingredient of the explanation of why the competitive success differs between countries. On these points see also Chapter 7.