7

Technology gaps in open economies

The main thrust of the analysis so far has been towards a better understanding of the international patterns of technical change and their influence on international trade patterns. The focus of the analysis has been largely microeconomic, in the sense that the prime objects of enquiry were individual sectors or groups of sectors. In this chapter, we turn to some of the macroeconomic implications of our analysis and findings. We shall in particular address the following question: What is the relationship between the pattern of technological change, on the one hand, and the pattern of macroeconomic growth on the other? In keeping with the spirit of this book, the investigation will be of an exploratory nature, given the relatively primitive state-of-the-art of economics in this area: most neo-classical growth models rule out *ex-hypothesi* all the problems in which we are most interested, such as international technological gaps, whereas the more 'classical' (post-Keynesian) growth models are of limited use, in so far as they are generally based on closed-economy and steady-state assumptions.[1] The most recent 'new' growth contributions (Romer, 1986, 1989, Lucas, 1988), particularly when concerned with open economy issues (see e.g. Grossman and Helpman, 1989, 1990a, b and c), clearly follow similar lines of concern. However, their treatment of technological change remains as yet rather traditional and, in our view, somewhat remote from the process described by many authors of the economics of technological change and summarised in Chapter 4.

Our aim in this chapter is not to develop a complete open-economy multisector model embodying the most relevant features of technical change, but, rather, to bring to the forefront the set of relationships which one might expect between the nature of technological change

among countries, and the stimuli and constraints that each national economy faces in its growth process.

It was suggested in the preceding chapter that absolute advantages in the form of product and process-related technological asymmetries are likely to be dominant upon comparative advantage mechanisms as determinants of each country's participation in world trade. Here we shall take – as the case of the broadening of 'new' trade theory to 'new' growth theory – the question a step further and ask whether a similar concept of dominance applies to the relationship between technology and macroeconomic growth in an open economy. The main assumptions of the preceding chapter will be maintained: technology is not a free good, but shows varying degrees of appropriability at the company and country level; one can identify relatively 'ordered' patterns of technical change that will allow technologies to be ranked as economically superior and inferior irrespective of income distribution; and, finally, the absolute advantages such technological advantages generate are likely to be a fundamental force shaping trade patterns. When considering the growth process of each economy, these properties of technical change have a number of important implications.

Let us start from three evident facts. First, the growth possibilities of each economy are technically limited by its production coefficients. Second, in open economies the patterns of production do not depend solely on the nature of domestic consumption and production coefficients, but also on the factors shaping international specialisation and international terms of trade. Third, if one economy buys commodities from another, it has got to be able to pay for its imports by means of its exports. Technology, as we shall see, affects all these variables in ways which contribute to the determination of both the constraints and the stimuli to growth.

It is not only the absolute technological levels of each economy that determine the maximum attainable per capita income and rate of accumulation, but also the relative technological levels between countries which affect growth possibilities through the balance of payment constraint. We shall first analyse a very simple case of two economies characterised by different production coefficients and a Ricardian mechanism of specialisation, taking into account the joint effect of international specialisation and the balance of payment constraint upon the growth possibilities of each economy (Section 7.1). We shall then expand the discussion to a dynamic framework and investigate the effects of technological innovation and imitation (Section 7.2). In Section 7.3, a more detailed consideration will be given to the overall pattern of interdependence brought about by the existence of international trade: in particular the possibility of processes of circular causation and virtuous and vicious circles in the patterns of growth. Finally, in Section 7.4 we shall discuss some of the empirical evidence on the relationship between technological change, trade and growth.

7.1 International specialisation, trade balances and growth possibilities: a simple model

In the following we shall present a highly simplified formal framework which is meant to be a sort of 'theoretical abacus' highlighting some linkages between technology gaps, patterns of specialisation and macroeconomic rates of activities. Further developments of the basic model can be found in Cimoli, Dosi and Soete (1986), Cimoli (1988) and Cimoli and Soete (1988).

Let us define two groups of commodities. The first group, which we call Ricardian commodities,[2] is traded solely on the grounds of the relative cost of production. A second group of commodities, innovative commodities, are produced and exported only by one country, where the product innovation occurred, irrespective of production costs. For the time being we shall focus on the former group. Let us start from the reformulation of a Ricardian model of trade provided by Dornbush, Fisher and Samuelson (1977) and assume a continuum of properly ordered commodities. There are two countries, A and B.

Simplifying the picture to the extreme, we start by assuming no inputs other than labour. Denote labour input coefficients as $a_1, a_2, \ldots, a_n$ for country A and $a_1^*, a_2^*, \ldots, a_n^*$ for country B. Commodities are conveniently indexed so that relative unit labour requirements are ranked in order of diminishing home country comparative advantage (advantages of country A in our definition).[3] This ranking is such that, in a discrete representation:

$$a_1^*/a_1 > \ldots > a_i^*/a_i > \ldots > a_n^*/a_n \tag{7.1}$$

Calling z each commodity, a function can be defined on a conventional continuum, say $[0,1]$:

$$A(z) = \frac{a^*(z)}{a(z)} \tag{7.2}$$

with

$$A'(z) < 0$$

International specialisation for each commodity in A or B will depend on relative unit labour costs (denominated in a common measure):

$$a(z) \cdot w \leq a^*(z) \cdot w^* \tag{7.3}$$

i.e.

$$\omega \leq A(z)$$

with

$$\omega \equiv \frac{w}{w^*}$$

where w and w^* are the wage rates in countries A and B respectively. Commodities will be produced in A or B depending on which one is cheaper at current wage rates and labour productivities. The borderline commodity, separating those produced in A and B, respectively, will be

$$\tilde{z} = A^{-1}(\omega) \tag{7.4}$$

with $A^{-1}(\omega)$ as the inverse function of A. The process of specialisation is visualised in Figure 7.1. For a wage ratio (w/w^*) equal to ω, country A specialises in the set of commodities from 0 to $\tilde{z}$ and country B in commodities from $\tilde{z}$ to 1.

It will be clear from Figure 7.1 that an increase in the domestic wage relative to the commercial partner will reduce the set of commodities which that country can competitively produce, and vice versa.

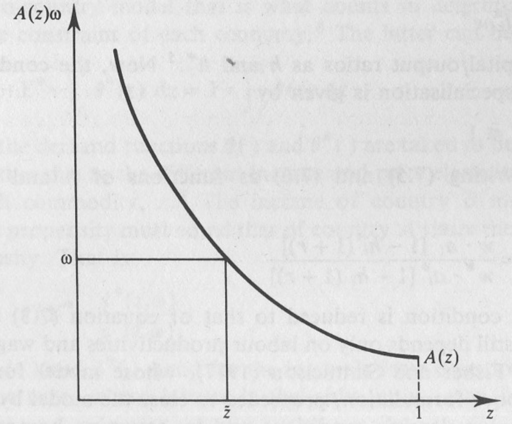


Figure 7.1 Specialisation with a continuum of 'Ricardian commodities'

It can be shown that the same result also applies in those cases where there are capital inputs and positive profits, provided that there is no 'reswitching of commodities'. This will be the case when:

(a) the rate of profit is identical across commodities and across countries;
(b) the capital/output ratios for each commodity are identical in A and B;
(c) all capital goods are domestically produced with labour inputs only.

Assumptions (a) and (b) seem to conform to much empirical evidence (cf. Chapters 3 and 4). Assumption (c), on the contrary, is very unrealistic. Below, we shall briefly discuss the properties of an economy where all capital goods are imported.

Under assumptions (a)–(c), the price equations for each final commodity are:

$$p_i = c_{ki} p_{ki} (1 + r) + w a_i \tag{7.5}$$

$$p_i^* = c_{ki}^* p_{ki}^* (1 + r) + w^* a_i^* \tag{7.6}$$

where the cs are capital ('machine') inputs per unit of final output, the p_ks are the prices of the machines and r is the rate of profit. The prices of the capital goods ('machines') are:[4]

$$p_{ki} = l_{ki} w \tag{7.7}$$

$$p_{ki}^* = l_{ki}^* w^* \tag{7.8}$$

Define the capital/output ratios as h and h^*.[5] Now, the condition of international specialisation is given by

$$p_i / p_i^* \lesseqgtr 1$$

However, rewriting (7.5) and (7.6) as functions of h and h^* and rearranging:

$$p_i / p_i^* = \frac{w \cdot a_i \, [1 - h_i^* (1 + r)]}{w^* \cdot a_i^* \, [1 - h_i \, (1 + r)]} \tag{7.9}$$

If $h_i = h_i^*$ the condition is reduced to that of equation (7.3) above:[6] specialisation still depends only on labour productivities and wage rates.

Dornbush, Fisher and Samuelson (1977), whose model forms the basis of the above formulation, proceeded to close the model by imposing labour market-clearing conditions and by assuming homotheticity (such as Cobb–Douglas) of the demand functions. We shall radically depart from that approach in order to account for what we consider to

be five fundamental properties of modern economic systems, namely:

1. Different commodities show a wide range of price and income elasticities.
2. In normal circumstances the rate of growth of each economy is not constrained by the supply of labour but by the requirement of balancing the foreign accounts.[7]
3. For a given state of technology, the rate of utilisation of the labour force is determined by the levels of macroeconomic activity.
4. Wage rates are also determined by institutional factors which grant them some degree of freedom vis-à-vis the prevailing labour market conditions.
5. Microeconomic processes of technological change are highly 'rational boundedly', diverse among firms, and generally full of mistakes. Thus, the rates of technological change cannot be 'inferred back' from the properties of theoretical steady-states, assuming 'representative agents' with 'rational technological expectations'. (Incidentally one may note that this is the spirit of many of the recent equilibrium growth models with endogenous technical change, such as Romer (1990).)

By bringing these hypotheses into the picture we will now be able to provide a link between the conditions for international specialisation and a 'Keynesian' determination of the levels of activity.

Let us start with the demand function. In the first instance we are interested in that portion of demand which goes to imports because in our two-country model that is what counts in determining the trade-balance constraint of each economy.[8] The latter can be written as:

$$Y^* \cdot \int_0^{\bar{z}} \theta^*(z) \, dz = Y \cdot \int_{\bar{z}}^1 \theta(z) \, dz \tag{7.11}$$

where the demand functions $\theta(\,)$ and $\theta^*(\,)$ are taken to be different from each other due to the different income and price elasticities with respect to each commodity, z.[9] The income of country B multiplied by its import propensity must equal that of country A times the latter's import propensity. That is:

$$Y / Y^* = \frac{\psi^*(z,\omega)}{\psi\,(z,\omega)} \tag{7.12}$$

where $\psi(\,)$ and $\psi^*(\,)$ stand for the integrals from equation (7.11). In the simplest case, where labour is the only input, each income will be:

$$Y = wN \tag{7.13}$$

$$Y^* = w^* N^* \tag{7.14}$$

with

$$N \leqslant L \text{ and } N^* \leqslant L^*$$

where N and N^* are the employment levels, less than or equal to the supplies of labour L and L^*, respectively.

In the more complex case with capital inputs and positive profits, equations (7.13) and (7.14) can be rewritten as:

$$Y = (1/s)wN \tag{7.13.1}$$

$$Y^* = (1/s^*)w^*N^* \tag{7.14.1}$$

where s and s^* are the shares of wages in national income.[10]

The system of four homogeneous equations (7.3), (7.12), (7.13) and (7.14) leaves four degrees of freedom in the determination of the seven unknowns (two levels of income, Y and Y^*, employment N and N^*, the wage rates w and w^*, and the border-commodity in the pattern of specialisation, $\bar{z}$).

The system defines the boundaries of all possible price-related and income-related adjustments, determined by:

(a) technological conditions;
(b) the composition of the demand baskets; and
(c) an interdependence constraint via trade balances.

Let us illustrate this point with the help of Figure 7.2. The S-line through the top left quadrant is the locus of the ratios between wages (w) which guarantee a certain specialisation commodity $\bar{z}_0$.[11] For that same commodity the TB line is the locus of equilibrium points for the trade balance.[12] In the simplest case of $Y = wN$, the angle (α) between any f-line and the w-axis is a straightforward measure of employment in country A and so is the angle (α^*) between any f^*-line and the w^*-axis, for country B.[13]

As an illustration, assume now a pair of wages, w_m and w_m^*. These wages must be feasible in the sense that they must be (in terms of own-produced commodities) equal to or less than the average labour productivity of the economy for any given specialisation as given by the S line in Figure 7.2.[14] In particular, suppose that w_m is the minimum socially acceptable wage in country A which equals average productivity of the economy with specialisation $\bar{z}_0$ defined by w_m/w_m^*.[15]

Moreover, suppose (for simplicity, although by no means analytically necessary) that economy A is at full employment, defined by the line f_T. The corresponding equilibrium income for country A is Y_T, the maximum income level. For country B, however, it is Y_T^*. This may correspond to less than full-employment income in country B. Say, B-

full-employment income is defined by the line f_T^*: when B specialises in commodity $\bar{z}_0$. However as illustrated in Figure 7.2 this cannot be achieved, given the trade-balance constraint. At point R, country B will suffer significant unemployment given by the line f_m^*.

It is important to note that despite unemployment in B, the pair w_m-w_m^* yields an equilibrium position in the sense that the specialisation is 'efficient' in static allocative terms: it satisfies equation (7.4) and thus corresponds to the dividing line between comparative advantages and comparative disadvantages. Let us call this microeconomic criterion of efficiency 'Ricardian efficiency'.

As can be seen from Figure 7.2, there is an entire set of points which

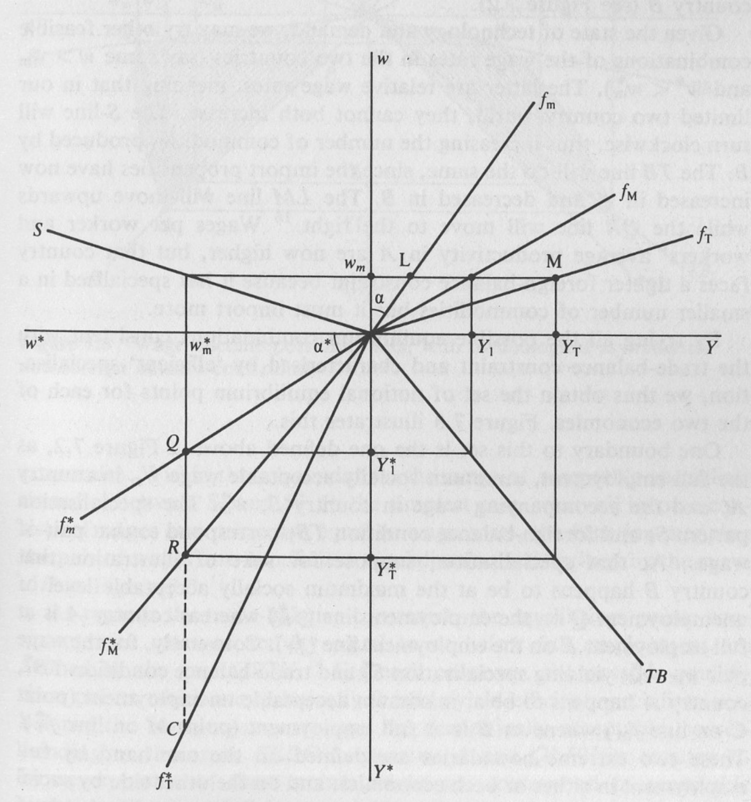


Figure 7.2 Specialisation, foreign balance constraints and income possibilities: an illustration

satisfy these equilibrium conditions while yielding less than full employment rates of activity in both economies: for example, incomes Y_1 and Y_1^* correspond to less than full employment in *A* (as defined by f_M) and an even lower level of employment in point *Q* in country *B* (as defined by f_m^*). The interdependence properties of trading economies are, in other words, such that their 'size' is reciprocally constrained by their trade balance for any given technological and demand condition. Thus, the set of notional equilibrium points between what could be called maximum acceptable unemployment, illustrated in Figure 7.2, for instance by the employment line f_m in country *A* and f_m^* in country *B*, and full employment or maximum employment consistent with the trade balance corresponds to the segment *LM* for country *A* and *QR* for country *B* (see Figure 7.2).

Given the state of technology and demand, we may try other feasible combinations of the wage rates in the two countries (say some $w > w_m$ and $w^* < w_m^*$). The latter are relative wage rates, meaning that in our limited two country world, they cannot both increase. The *S*-line will turn clockwise, thus increasing the number of commodities produced by *B*. The *TB* line will do the same, since the import propensities have now increased in *A* and decreased in *B*. The *LM* line will move upwards while the *QR* line will move to the right.[16] Wages per worker and workers' average productivity in *A* are now higher, but that country faces a tighter foreign-balance constraint because it has specialised in a smaller number of commodities but it must import more.

By trying all the possible equilibrium combinations consistent with the trade-balance constraint and characterised by 'efficient' specialisation, we thus obtain the set of notional equilibrium points for each of the two economies. Figure 7.3 illustrates this.

One boundary to this set is the one defined above in Figure 7.2, as the full employment, minimum socially acceptable wage w_m in country *A*, and the accompanying wage in country *B*, w_m^*. The specialisation pattern S_T and foreign-balance condition TB_T correspond to that pair of wages. At that specialisation, suppose for sake of illustration that country *B* happens to be at the maximum socially acceptable level of unemployment *Q* on the employment line (f_m^*) whereas country *A* is at full employment *E* on the employment line (f_T). Conversely, for the wage pair w_M-w_M^*, yielding specialisation S_T^* and trade-balance condition TB_T^*, country *A* happens to be at maximum acceptable unemployment (point *C* on line f_M) whenever *B* is at full employment (point *M* on line f_T^*). These two extreme boundaries are defined on the one hand by full employment in either or both economies, and on the other side by social and institutional factors, the maximum socially acceptable level of unemployment and/or the minimum acceptable wage in each of the two

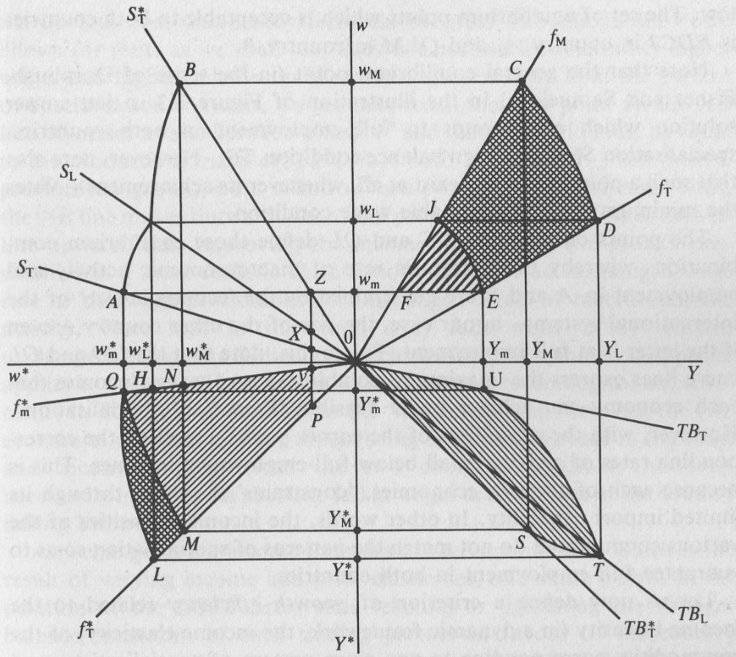


Figure 7.3 Wage–income possibility sets, with technological asymmetries and foreign balance constraints

economies. Within these boundaries, the range of acceptable specialisations lies between S_T and S_T^*. In the simplest case, when all income consists of wages and prices are equal to wage costs, the function mapping the pair of wages into an efficient specialisation is described by the curve *AB* in Figure 7.3.[17]

As regards the trade-balance constraint, the equilibrium points consistent with rates of activity equal to or below full employment are defined by the area *OSTU*.[18] For each economy, the possible equilibrium points which are technically feasible yield efficient specialisations, balance the foreign accounts, and are domestically acceptable, corresponding to the areas *FEDC* in country *A* and *QLPV* in country *B*. However, some of these points might not correspond to acceptable situations for the *other* country, in the sense that they might correspond to rates of unemployment which are too high, or wages which are too low. The set of equilibrium points which is acceptable to both countries is *EDCJ* in country *A*, and *QLM* in country *B*.

Note that the general equilibrium point (in the sense of Dornbush, Fisher and Samuelson) in the illustration of Figure 7.3 is that corner solution which corresponds to full employment in both countries, specialisation S_L and foreign balance condition TB_L. However, note also that such a point might not exist at all, whenever its achievement violates the minimum socially acceptable wage condition.

The points on the lines *DC* and *QL* define those equilibrium combinations whereby the maximum rate of macroeconomic activity and employment in *A* and *B* are constrained by the 'economic size' of the international system – in our case, the size of the other country – even if the latter is at full employment. To see this, note that the *CD* and *QL* curve lines express the 'maximum' combinations of wages/incomes that each economy can achieve under feasible 'Ricardian' specialisations. However, with the exceptions of the corner points *L* and *D*, the corresponding rates of activity entail below-full-employment incomes. This is because each of the two economies, 'constrains' the other through its limited import capability. In other words, the income intensities of the various commodities do not match the patterns of specialisation so as to guarantee full employment in both countries.

Let us now define a criterion of *growth efficiency* related to the income intensity (in a dynamic framework, the income elasticity) of the commodities corresponding to any given pattern of specialisation, and thus to the levels of foreign demand they generate. The foregoing example highlighted the general possibility of mismatch between Ricardian (static allocative) efficiency and growth efficiency. As a parenthesis, it is worth noting that from a normative point of view this also illustrated the possibility of trade regimes which were different and better, in terms of growth possibilities, than free trade.

The line *ED* for country *A* and *LM* for country *B*, in Figure 7.3 correspond to the set of equilibrium combinations whereby the full employment constraint is met before the foreign-balance constraint: it is the domestic economy which puts a ceiling on world development via its own 'size', and thus its capacity to absorb exports from the rest of the world. Another way of saying the same thing is that there is an 'over-competitiveness' of the domestic economy which tightens the foreign-balance constraint for the rest of the world.[19]

The *position* of the *AB* line depends in a straightforward manner on the absolute technological levels of each economy. Holding the relative technological gap between the two economies constant, the higher the absolute technological levels (i.e. in our case, the higher average labour productivities), the more 'outward' the *AB* line will be: this illustrates the obvious fact that steady technical progress throughout the world allows for (but, as we shall see, does not necessarily determine) higher wages and higher incomes in all countries, even if we hold the pattern of specialisation constant. To see this, recall that any point on the *AB* line expresses a ratio between w and w^* and that that ratio must be equal to the productivity ratio $a(z)/a^*(z)$. If both $a(\ )$ and $a^*(\ )$ fall (hence, productivity grows), both w and w^* can proportionally increase. Thus, the *AB* line moves outward. Technical progress in *A* only pushes the *AB* line upward, thus improving the income possibilities (i.e growth possibilities in a more realistic formulation) of *A* for an unchanged wage rate or the wage possibilities for unchanged levels of macroeconomic activity. Note that in this case, $a(z)$ falls while $a^*(z)$ remains unchanged. Hence the S_T^* line moves clockwise. The symmetric opposite applies to wages and incomes in *B*, for domestic technological improvements in *B*. Thus, an increase in the 'technology gap' between the two economies allows for, other things being equal, an increase in the wage and income gaps between the two countries, without, however, necessarily implying an absolute fall in wages and incomes in the country falling behind.[20]

Any change in the income intensity of the commodities, which is the result of varying income and price elasticities, will cause a shift in the position of the *OSTU* area, thus relaxing or tightening the foreign-balance constraint of each trading partner in favour of the country producing commodities with a higher income intensity, for any given specialisation.

Finally, the length and the slope of the *AB* line can be taken to represent the scope of cost-related and specialisation-related adjustment processes for any given state of technology and demand. The length depends on two factors: first, the intracountry variance in labour productivity, which determines the sensitivity of the patterns of specialisation to changes in wage rates, and, second, the socially determined boundaries to the variations in wages and unemployment rates. The slope depends on the relative degrees of homogeneity in the production coefficients across countries and across commodities.

By *homogeneity* of each country we mean the degree of similarity in the productivity leads or lags between the various commodities it produces (i.e. the similarity in the commodity-specific absolute advantages/disadvantages).[21] Different degrees of homogeneity also determine the sensitivity of the patterns of specialisation to changes in wage rates. In the case depicted in Figure 7.3, for example, country *B* requires a relatively small change in wages to achieve large shifts in specialisation as compared to country *A*.

We may now start to appreciate more fully the meaning of *technological dominance* over comparative advantage mechanisms of specialisation as a determinant of income and wage levels. If each economic system is relatively *tight*, in the sense that:

(a) it has relatively stringent constraints in terms of its maximum unemployment rate and minimum wage;
(b) it is confronted with a relatively sharp discontinuity between the average technology gap/lead in the group of commodities it exports and those that it imports;[22] and
(c) its production structure is relatively homogeneous (so that the *inter-commodity variance* in the labour productivity gaps vis-à-vis the partner regarding domestically produced commodities is low);

it will be more likely that the range of the country's possible equilibrium points is *relatively limited*: the *AB* line is short while the f_m and f_T lines are close to each other, as are the f_m^* and f_T^* lines. In this tight case, only technical progress will be able to induce significant improvements in incomes and wages for any configuration of the international system.

It must be stressed that the model developed so far is concerned with the boundaries of the set of points consistent with efficient microeconomic specialisation (in a static allocative sense) and with the macroeconomic requirement of balancing the foreign account. It does *not* tell us at which point each economy will settle. This will be a function of the domestic mechanism of demand formation and its international interdependence via import and export flows. In other words, we can identify the areas *JEDC* for country *A* and *QLM* for country *B* as the areas of feasible specialisations and acceptable Keynesian adjustment processes.

More precisely, taking the simple model presented here as an illustration of a more general one, accounting also for investments, profits, etc., we can read any horizontal movement in the country *A*- set and any vertical movement in the country *B*-set as a *Keynesian process* of change in equilibrium income. Conversely, any vertical movement in the *A*-set and horizontal movement in the *B*-set can be defined as a *Ricardian process* of change in equilibrium specialisation. Both processes can operate only under strong interdependence requirements, so that there must be an international symmetry in the movements of wages and incomes. Disequilibrium variations may of course occur: macroeconomic – via the exchange rate and variations in 'absorption' – and microeconomic adjustment processes – via changes in the competitiveness of each commodity and intercommodity mobility of capital – will react to every imbalance. The time profile of these adjustment processes will determine the actual path followed by each country.

There is, however, an important difference between these Keynesian and Ricardian adjustment processes. The former are straightforward positive- (or negative-) sum games: everyone gains as, for example, in the movement from *J* towards *D* in country *A* and from *H* to *L* in country *B*, or everyone loses, as in the case of movements in the opposite direction. Ricardian processes, on the other hand, do involve trade-offs: there is certainly a trade-off between domestic and foreign wages, sometimes also a domestic trade-off between wage and income levels – in the case of country *A* for example, for wages between w_L and w_M; in country *B*, for wages between w_L^* and w_M^*.[23]

We may to some extent interpret these Ricardian adjustment processes as the real microeconomic counterpart of devaluation/revaluation adjustment mechanisms. In essence, each devaluation is a downward change in the domestic real wage vis-à-vis foreign wages.[24] Taking a closer look at Figure 7.3, one can appreciate how this simply shifts possibilities of growth from one country to another. Take, for example, any downward adjustment of wages in *A* from point w_M: if income is not correspondingly increased along the *CD* line, the expansion of country *A*'s income (from Y_M to somewhere short of the income corresponding to the *CD* line) is 'paid for' with less than full employment rates of activity in *B*. More generally, the model and framework presented here brings together three sorts of economic analysis which have traditionally been kept separate from each other:

(a) the 'Keynesian' account of macroeconomic levels of activity in open economies;
(b) the microeconomic processes of specialisation; and
(c) the effects of technological differences between and within countries.

The greater the degree of 'tightness' of each economy – as defined above – the more the technological dominance will apply to both Ricardian and Keynesian processes of change from one equilibrium position to another; in other words, only the outward movements of the *CD* and *QL* frontiers are likely to disentangle unfavourable (sub-optimal) set-ups of any economy. This is even more so if one thinks of the way Ricardian and Keynesian adjustment processes are related. Suppose country *A* tries to increase competitiveness by decreasing its real wage starting from wage w_M and income Y_M: more often than not, a 'Keynesian process' (deflation) is used to achieve the 'Ricardian' result. If the trade partner is also forced to use the same instrument, being very sensitive to the foreign-balance constraint, the resulting path may closely follow the *CF* line downwards in country A and push from M towards N in country B. In other words, *everyone* may end up in a *worse* position in terms of employment or income or both. This particular case highlights a general characteristic of the international system: while it requires a high degree of symmetry and synchrony in the process of change, it does not automatically provide any functional mechanism which guarantees it. We shall return to this question below.

Before analysing the functional mechanisms which determine the *actual* combinations between wages, specialisation, income, and employment level at greater length let us mention some other interesting properties of the system to conclude this section:

1. It may well be that full employment specialisation for one of the two countries can be achieved only for wage rates *below* the minimum acceptable level (or even below the subsistence level in the case of a technologically backward country). This result is more likely if a country is confronted with a very wide domestic productivity gap between a few modern sectors and the rest of its tradeable commodities or if the income intensity in the world market of the commodities in which it specialised, is very low.[25]
2. Allowing for profits and investments and relaxing the simplifying hypothesis that all capital goods are domestically produced yields some further interesting results. Let us start from the opposite case and assume that all capital goods are produced by country A. Consider now the position of country B. Any given downward change in country B's wages has a lower or even perverse effect upon the country's pattern of specialisation (the S-line) and trade-balance constraint (the TB-line). In fact, capital inputs have now to be paid for at a higher real price, while the terms of trade have deteriorated. If the capital/output ratios in B are sufficiently high,[26] it may well be that a decrease in the domestic real wage (e.g. through a devaluation) yields a *tighter* trade-balance constraint with a *lower* number of commodities efficiently produced.

On a more speculative note, one might even suggest the following hypothesis: the sensitivity of both the pattern of specialisation and the trade-balance constraint to Ricardian adjustment processes is proportional to the degree of self-sufficiency (or, more generally, the net trade balance) in the sectors producing capital goods.[27] If this were to hold true in general, then adjustments based on relative wage and exchange rates are easier (and less painful) for relatively developed countries than for less developed ones, whose capital goods sector is generally small or non-existent.

7.2 Technological dynamics: the changing patterns of specialisation and international distribution of growth possibilities

In the preceding section, we discussed some of the effects of technological innovation on the set of equilibrium incomes and wages in two countries A and B. Suppose now that country A – the North – is the more advanced (innovative) country and B – the South – the less advanced one. We illustrate this particular case in Figure 7.4, using the same terminology as in Figure 7.3. Absolute productivities of the 'North' are always higher than of the 'South' – so that the A^1B^1 line always rests above the 45-degree line cutting the w-w^* quadrant. Moreover, the income-intensities (i.e. dynamically, the income elasticities) of B-exports into A-incomes are relatively low: so, the $OS^1T^1U^1$ area remains relatively near the x-axis. Finally, we assume that in country A the maximum-wage/minimum-employment is f^1_{m} and the full employment line is f^1_{T}. In country B, the minimum socially acceptable employment is f^{1*}_{m} and the full employment is f^{1*}_{F}. Given the efficiency gap between the two countries and the demand patterns, full employment in B is unattainable even when country A is indeed at a full-employment income (say, at Y^1_{T}). The area $K^1L^1M^1$ is, as depicted in Figure 7.4, located within the boundaries given by f^{1*}_{m} and f^{1*}_{F}. Keeping technology constant, how could the position of B notionally improve? One possibility would have been a bigger 'size' of country A: other things being equal, a larger 'advanced' country would imply a clockwise turn of the f^1_{T} line, greater absorption of imports from B and, hence, higher income and employment possibilities for B, holding B-wages constant. Conversely, one can imagine a clockwise rotation of the lines TB^1_{T} and TB^{1*}: that is, a relative increase of the intensity of B-export in A-income (or, on the contrary, a decrease in the intensity of A-exports in B-incomes). As a consequence, the income and employment possibilities would increase (the lines f^{1*}_{T} and f^{1*}_{F} would turn anti-clockwise), leaving an unchanged income for country A and also an unchanged pair of 'efficient' wages (w^1_{T} and w^{1*}_{T}). It is obvious though, as discussed in the previous section, that all innovation processes which increase labour productivity in A will widen the gap in income and wages between the two countries, even if they leave their absolute levels in the 'backward' country unchanged. Conversely, all technological imitation and/or technology transfer to country B will decrease the gap between the two countries by increasing wages and incomes in B relative to A. In other words, and as discussed at greater length in Chapter 5, we now assume a situation whereby innovative processes induce divergence and all imitation processes induce convergence between two countries A and B. The

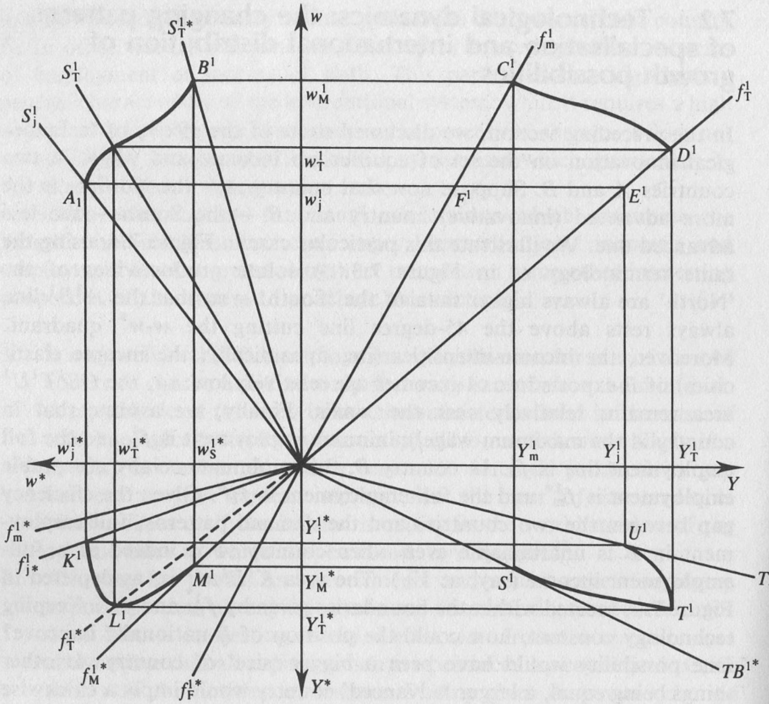


Figure 7.4 Wage–income possibility sets: a North–South illustration

model will account for a straightforward link between technology gaps and income (and wage) gaps between countries.[28]

We will also bring into the picture the innovation commodities, neglected so far in the analysis for the sake of simplicity. The innovative commodities can be produced only by one country, A, irrespective of relative costs, for the simple reason that only that country knows how to produce these, given its innovative lead. We may therefore re-arrange the 'continuum of commodities' on a range (o, l) as shown in Figure 7.5. The range between o and r_0 covers innovation commodities, the range from r_0 to l the Ricardian ones. As regards the latter, the diagram simply highlights what has already been stated above: process innovations (i.e. across-the-board increases in productivity) in A shift the R_0R_0' line to R_1R_1', thus allowing for a wider specialisation (from $\bar{z}_0$ to $\bar{z}_1$) for a given wage ratio (ω_0) or a higher wage for an unchanged specialisation ($\bar{z}_0$).

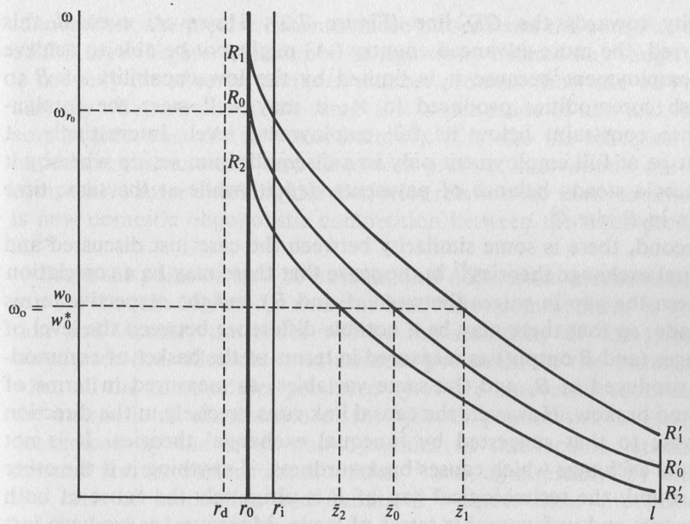


Figure 7.5 International specialisation with a continuum of 'Ricardian' and 'Innovation' commodities

The opposite applies to process imitation as depicted by the shift to R_2R_2'.

The introduction of innovative commodities into the formal analysis, developed in the preceding section, brings to the forefront a number of additional interesting features.

First, there is now a clear limit to wage-induced changes in specialisation, i.e. to the Ricardian adjustment process. This is given by r_0, the borderline commodity between the innovative and Ricardian commodities. It can be easily seen from Figure 7.5 that any increase in ω (e.g. any decrease in country B's wages) above w_{r_0} does not have any effect on specialisation but only worsens the terms of trade for B.[29] In terms of Figure 7.4, no downward change in w^* will turn S_T^{1*} and TB^{1*} clockwise. The only effect such change will have is to move the equilibrium combination towards lower levels of macroeconomic activity for *both* countries. If some gain in employment is achieved in B, this is paid for by lower wages, possibly even with a lower aggregate income as a result.

This is an interesting case in other respects also. Country B, in order to achieve full employment without falling in the trap of 'immiserizing growth', is in the last resort dependent on a 'Keynesian process' occurring in A, i.e. on the willingness of the latter to push macroeconomic activity towards the *CD* line (Figure 7.3). However, even if this occurred, the more advanced country (A) might *not* be able to achieve full employment because it is limited by the low capability of B to absorb commodities produced in A: it may well meet the foreign-balance constraint below its full employment level. Interestingly, A might be at full employment only in a disequilibrium set-up whereby it finances a steady balance of payments *deficit*, while at the same time wages in *B rise*.[30]

Second, there is some similarity between the case just discussed and unequal exchange theories[31] in the sense that there may be a correlation between the gap in wages (between A and B) and the respective terms of trade, so that there may be a notable difference between the level of B wages (and B output) as measured in terms of the basket of commodities produced in B, and the same variables, as measured in terms of demand baskets. However, the causal link runs precisely in the direction opposite to that suggested by 'unequal exchange' theories. It is not unequal exchange which causes backwardness, if anything it is the other way round: the technological gap of B is ultimately the cause of both low wages and unfavourable terms of trade. Moreover, as we have just seen, there may not be any objective interest in country A to keep wages in B down: quite the contrary, the latter may limit the levels of country A's macroeconomic activity via the trade-balance constraint.

Suppose now product innovations increase the total number of commodities produced in the system (thus pushing l, in Figure 7.5, to the right), while at the same time moving the borderline commodity between the innovative and Ricardian commodities, from r_0 to r_i. Conversely, all product imitations move the borderline commodity to the left, say to r_d.

Let us first consider the effects of *product imitation*. The latter increases the space of the 'Ricardian' adjustment processes and turns S and *TB* (Figure 7.3) in favour of the imitating country. Suppose the commodities which shift (from 'innovative' to Ricardian) happen to be proportionally distributed along the entire *RR'* range of Figure 7.5. Then, product imitation will always improve both the pattern of specialisation and the balance of payment constraint for B, even if $\tilde{z}$ happens to be within the range of Ricardian commodities already. As regards product innovation, the opposite applies.[32]

The presence of innovative commodities tends to relax the link between wages, productivity and prices as implied in the wage–income possibility sets illustrated in Figures 7.2, 7.3 and 7.4.[33] As far as 'Ricardian' commodities are concerned, Ricardian adjustment mechanisms always check the limits of the variation of wages vis-à-vis productivity growth, and of prices vis-à-vis unit costs, since any excess will be paid with loss of specialisation. When we allow for product innovations, the picture becomes more blurred and the contours of the *JEDC* area (Figure 7.3) cannot be rigorously defined any longer. This is not only the effect of an index number problem (how can we reasonably say when income is 'the same' if it is also made of new and 'better' commodities that did not exist before?), it is also the reflection of an important characteristic associated with product innovations: the major competitive force checking the cost/price relation for these commodities is now domestic oligopolistic competition between the firms producing it.[34]

From the point of view of international adjustment mechanisms, one can see that the higher the share of innovative commodities in production and income, the lower will be the sensitivity of the system to wage/price (i.e. Ricardian) adjustment processes. In the extreme case when all the commodities produced by A are innovative commodities, the international distribution of the 'growth possibilities' is essentially determined by the levels and dynamics of the income intensity of demand for the various commodities,[35] and, dynamically, by the relative rates of innovation and imitation.[36] Under these circumstances, holding technology constant, the S-line will be fixed, whereas the position of the *TB* line will depend on the income intensities and the only adjustment process from one equilibrium to another will be a Keynesian one (east/westward for country A and south/northward for country B, in terms of Figure 7.3). Conversely, only innovation/imitation can change the international pattern of specialisation, jointly with the shape of the balance of payment constraint.

From a more normative point of view, in such a world any one country which happens to fall below full employment may only rely, in the short run, on 'international Keynesianism' (or domestic Keynesianism and import protection), and, in the long run, on imitation/innovation policies, whereas cost-related adjustments may be perverse in so far as they backfire on the terms of trade, leaving specialisation unchanged. From this perspective, one may even account for a couple of extreme cases whereby an improvement of both the balance of payment constraint and the domestic possibilities for growth are achieved through a revaluation of the exchange rate and the domestic real wage (see, e.g. van der Ploeg, 1989).

7.3 Technological conditions, foreign balances and effective demand

So far, the analysis has focussed on the 'outer boundaries' of the various equilibrium combinations which are consistent with a balanced foreign account and yield efficient specialisation. The question as to which one of these points is actually achieved is partly addressed in this section. In order to do so, one must also account for the factors which determine levels of domestic macroeconomic activity.

Let us start with the old-fashioned macroeconomic identity:

$$Y = C + I + X - M \tag{7.15}$$

where Y equals income, C consumption, I investment, X exports, and M imports.[37]

We already have the analytical expressions for exports and imports.

$$X = \psi^*(\ ) \cdot Y^*$$

$$M = \psi(\ ) \cdot Y$$

The consumption function will be assumed to be stable with average (= marginal) propensity of consumption equal to c. For analytical purposes it is useful to differentiate, following Kaldor and Pasinetti, between consumption from wages (c_w) and consumption from profits (c_k). In the extreme case of $c_w = 1$, equation (7.15) can be rewritten as:[38]

$$Y = c_k Y + (1 - c_k)W + I + \psi^*(\ ) \cdot Y^* - \psi(\ ) \cdot Y \tag{7.15.1}$$

where W is the total wage bill. Total employment in the economy N is equal to Y/π, with π equal to the weighted average of labour productivities in the production of each commodity z (in the range between 0 and $\bar{z}$) and in the production of the corresponding capital goods.[39] Since $W = wN$, substituting and rearranging gives:

$$Y = \frac{1}{[1 + \psi(\ ) - c_k - (1 - c_k)(w/\pi)]} [\psi^*(\ ) \cdot Y^* + I] \tag{7.16}$$

This is an alternative formulation of the Keynesian multiplier, where exports and investments are taken to be, as usual, the two 'autonomous' demand items.

The same equation can be written for country B:

$$Y^* = \frac{1}{[1 + \psi^*(\ ) - c_k^* - (1 - c_k^*)(w^*/\pi^*)]} [\psi(\ )Y + I^*] \tag{7.17}$$

To the extent that the usual trade-balance constraint applies to both countries:

$$Y/Y^* = \psi^*(\ )/\psi(\ )$$

The system, however, maintains some degrees of freedom,[40] which account for both a somewhat institutional determination of wage rates (and thus income distribution within each country) and the interdependence condition between the sizes of the two economies. Dependent on

the initial conditions and the adjustment paths of the endogenous variables, the system may well fluctuate within the shaded areas of Figure 7.3, possibly following paths characterised by (nearly) balanced trade, (nearly) efficient specialisation and *below full employment* rates of macroeconomic activity. A study of these paths requires the introduction of additional stylised facts with regard to the *relative intensity and speed* of the adjustment processes which are beyond the scope of this book and would most likely require an explicit formalisation of some evolutionary microfoundation of macrodynamics.[41] Some qualitative considerations might, however, give an indication of how this will occur.

As regards changes in wages (expressed in terms of an internationally comparable 'real' measure), one may reasonably assume that they tend to adjust to imbalances in both foreign trade and the labour market. Within the present framework – which is strictly real – exchange rate variations are directly expressed as variations in the domestic real wage, as are the effects of different unemployment rates. In other words, these are the 'Ricardian' adjustments to foreign imbalances, and what we could term 'classical' adjustment processes to the labour market. Wages, on the other hand, enter the determination of the domestic rate of activity via the multiplier: any downward adjustment of wages – in the stylised framework presented here – implies, other things being equal, a decline in endogenously generated aggregate demand. In other words, they affect 'Keynesian' adjustment. Thus, the system exhibits a clear duality in the role of wages. On the one hand, the wage level bears a negative relationship with the trade-balance constraint and, as a consequence, has a negative effect on employment levels. On the other hand, wages appear in the multiplier to have a positive effect proportional to their real level and, as a consequence, a positive effect on employment.[42]

A particular case is that whereby the system may tend to overshoot in the reaction of wages (via exchange rates) to imbalances in foreign trade, thus depressing aggregate demand at home and, indirectly, abroad. This is more likely to apply if the patterns of specialisation are slower to adjust to trade imbalances than wages and income levels. The more this is the case, the more the behaviour of the system will approach that of a purely 'Keynesian' one, with rates of activity determined primarily by autonomous investments and by rather sticky foreign-trade multipliers.

The duality in the role of wages is likely to define relatively narrow adjustment paths, both within each economy and in the world as a whole, limited as they will be by trade-balance constraints on the one hand and macroeconomic demand depression on the other.

Finally, it may be noted that, for any given pattern of income intensity for the various commodities, wages bear a close relation to the average technological levels of each economy:[43] in a more realistic formulation, to the technological levels of the vertically integrated sectors generated by the set of tradeable commodities that each economy produces: see Pasinetti for further details (1981). In some loose sense, these average technological levels define the 'centre of gravity' around which the adjustment processes take place. International wage differentials are, in other words, related to the average technological gap/lead between countries.

With respect to investment, the assumption about its strict exogenous nature can now be abandoned. Investments can then be subdivided into the following three parts:

(a) an induced part, via the familiar accelerator-stock adjustment mechanisms;
(b) a part related to the changes in specialisation: a gain in commodities will require a related investment in new capacity, and, vice versa, a loss in commodities will imply a related disinvestment; and
(c) an exogenous part, stemming from innovation opportunities in each economy.

The difference between the *actual* level of income, i.e. that level of income endogenously determined by the autonomous items of demand and the multiplier, and full employment income, can be referred to as the *Keynesian gap*. Technology plays a crucial role on both sides of this gap. On the one hand, it determines in a straightforward manner the full employment income, once given the supply of labour (L), as $Y_{\max} = \pi L$, where π is labour productivity. On the other hand, it affects the *actual* rate of macroeconomic activity in two separate ways: first, technology gaps and leads determine, as we saw in Section 7.1, to a large extent the international distribution of growth stimuli and constraints via import and export schedules; and second, there is the determination of the innovation opportunities associated with 'autonomous' investment.

As one of us has argued elsewhere (Dosi and Orsenigo, 1988), there is no *a priori* guarantee that these dual effects of technology will yield actual levels of income equal or close to the maximum ones.

A similar set of considerations to the ones suggested in the preceding section on the possible dominance of technological conditions over the boundaries of the notional equilibria applies *a fortiori* to the actual paths achieved. If (a) the technology gaps/leads are relatively homogeneous for each economy (so that the space for changes in specialisation related to 'comparative advantages' is low), (b) the income intensities of the various commodities differ widely, and (c) the proportion of innovative to Ricardian commodities is high, then the two countries will be, so to speak, stuck in their respective positions, despite any possible Ricardian adjustment mechanism at work. Only technical change can then redefine the pecking order in terms of wages and incomes while in the short term exogenously induced 'Keynesian processes' (e.g. through fiscal policies) will be limited by the interdependence of the international system.

7.4 Technological progress and economic dynamics: an overview

From what has been said so far, it will be clear that technical change superimposes some dynamic mechanisms of paramount importance on the 'stationary' Ricardian and Keynesian adjustment processes ('stationary' in that one theoretically assumes them to operate on the grounds of given technologies and demand preferences).

In Section 7.1 we saw how technological innovation and imitation improved the trade-offs implicit in the relation between wages, income and international competitiveness, and moved the boundaries of the set of notional macroeconomic equilibria that one country can achieve. We now discuss the effects of technical change on the *actual* levels of income (and the correlated growth patterns). For the sake of simplicity, we will stick to the dichotomy between process and product innovations: these two 'ideal types' help in highlighting the economic effects of the process of technical change which can be placed on a continuum ranging from pure productivity increasing to pure additions to the basket of intermediate and consumption commodities.[44]

Let us first consider productivity-increasing innovations. We know from the preceding sections that they expand the boundaries of the growth possibilities of the economies concerned. The movement of the maximum feasible income for a given labour force is obviously defined as $\dot{Y} = \dot{\pi}$ where the dots stand for rates of change. The *actual* percentage change in income (starting from an equilibrium position) will be:

$$\dot{Y} = \dot{E} + \dot{A} \tag{7.18}$$

where $\dot{E}$ is the percentage change in the multiplier, as in equation (7.16), and $\dot{A}$ is the change in the autonomous items of demand. In the simplest case when all domestic expenditure is endogenous and income is written as a straightforward function of export levels and import propensities ($Y = 1/mX$), the elasticity of income to productivity will be a function of the export and import elasticities to the same productivity change.

With sticky baskets of consumption, it is interesting to note that whenever such pure productivity-increasing innovations do not lead to any increase in real wages and do not influence the domestic investment propensity, their sole positive effect upon income levels stems from the gains in foreign competitiveness.[45]

A pure process innovation increases the efficiency of labour inputs, decreasing the total labour force required to produce a certain amount of physical output and, thus, the size of the multiplier which also operates by means of workers' consumption. In a closed economy, the compensation effect may well be rather weak. In traditional, general equilibrium models, such a compensation is generally guaranteed by three hypotheses. First, prices of commodities and primary inputs are assumed to change contextually to imbalances in any market. Second, there must be at least substitution in consumption between different commodities (and possibly also substitution between techniques of production). And third, all this supposedly occurs via adjustment processes that, to be fair, have never been fully specified in their dynamics.

This is not the place to criticise these various hypotheses in any detail.[46] Suffice it to say that, as opposed to these hypotheses, the analysis presented in this book starts from the view that (a) prices are rather close to costs of production under conditions of constant or increasing returns; (b) there is only a very limited number of techniques available at any one time, which can generally be ranked as superior or inferior irrespective of relative prices (as argued in Chapter 4); (c) that demand for consumption commodities follows Engel-like patterns, with relatively limited price-induced substitution; and (d) that economic processes are by nature sequential and irreversible:[47] 'disequilibrium' decisions have effects which spread over the future.

These features of the economic system also constitute the 'microeconomics' of a Keynesian adjustment process: quantities adjust to variations in the direct and indirect effects of the autonomous elements of demand in a way whereby wages play the double role of being an item of costs (and thus a determinant of prices and competitiveness) and an essential item of aggregate demand generation through the multiplier.[48]

Consider again the particular case of a pure process innovation when real wages remain constant, so that prices in terms of international currency fall (cf. equations (7.5) and (7.6)). The $A(z)$ schedule in Figure 7.1 will shift – due to a changed 'productivity gap' between the two economies – and so will the borderline commodity $\tilde{z}$.

The net effect on income of the process innovation will stem from the relative impact of (a) positive specialisation and in a more general model, the price elasticity effects on exports and imports; and, (b) extending beyond the model of Section 7.3, the negative effect on the domestic generation of demand, as a consequence of the reduced

consumption capabilities of a reduced employed labour force. Two properties are worth noticing.

First, a fundamental difference with Ricardian adjustment (i.e. the devaluation case) lies in the fact that improved competitiveness must not be paid for in terms of falling wages: the latter may remain stable or even increase slightly. However, in analogy with the devaluation case, there is a beggar-my-neighbour element, in so far as the entire increase in domestic income (if any) could lead to a deteriorating competitiveness and possibly even lower growth possibilities for the trading partner.[49]

Second, we suggest that there is no endogenous force which guarantees that *in general* the potential level in income (that implicit in $\dot{Y} = \dot{\pi}$) will be achieved: in other words, the *Keynesian gap* between potential and actual rates of growth may widen.[50] If this occurs, the trade balance of the trading partner will become tighter and trigger off a process of international feedbacks which might even lead to an international growth rate lower than the pre-innovation rate. Conceptually identical considerations apply to pure process imitations.

Generally speaking, irrespective of what might happen to the absolute value of the growth rates of each economy, the *relative* rate of growth of the country undertaking the process innovation will always increase as compared to the other economy. In other words, the argument relating all innovative processes to *diverging* growth tendencies does not only apply to the boundaries of the potential equilibrium; it also applies to *actual* incomes (and rates of growth).

Let us now consider the case of a pure product innovation: a straightforward addition to the basket of consumption goods. Its impact upon foreign competitiveness will clearly be positive. The introduction of such a commodity will also be associated with an increase in autonomous investment. Thus, domestic income will increase. As a consequence, imports, too, will most likely increase.[51] At the end of the day, both incomes of the two countries (or, for that matter, both rates of growth) might have increased, although the increase in the innovative country (say, country A) will be higher than in B. In other words, the product innovation (at least, partly) will have *paid for itself*: while it increased country A's exports, relaxing its balance of trade constraint, at the same time it pulled up both country A's income (via the joint effect of autonomous investment associated with that innovation and increased exports) and country B's income (via increased import absorption in A and, thus, a stronger foreign-trade multiplier in B).[52] Considerations of a similar nature apply to product imitations in B.

These two ideal types of innovation – purely productivity-increasing or purely additional to the consumption basket – are highly unrealistic.

The overwhelming majority of innovations contain features of both. The foregoing discussion, however, helps in bringing to the forefront the different impact of a simple increase in the efficiency of the economic system on the one hand, and the generation of new investment and new market opportunities on the other. Since the characteristics of technical change do not allow one to put forward, *a priori*, any hypothesis of constancy in the relative balance between these two fundamental properties, one may also expect long-term variations in the endogenously generated rate of growth and in the *Keynesian gap* between the actual growth rate and the maximum rate which would guarantee full employment of the labour force, reflecting shifts in the balance between product and process innovation.

We now have all the elements for a synthetic account of the growth process under conditions of technical change. Reconsider equation (7.2). We may define the rate of productivity-increasing innovation in country A as:

$$\alpha = \frac{\mathrm{d}(a(z))/\mathrm{d}t}{a(z)} \tag{7.19}$$

whereas the rate of productivity-increasing imitation/diffusion in B is:

$$\alpha^* = \frac{\mathrm{d}(a^*(z))/\mathrm{d}t}{a^*(z)} \tag{7.20}$$

The change in specialisation among the 'Ricardian' commodities, as expressed by the change in $\tilde{z}_t$, will be a function of the change in wages in both countries, relative to their rate of process innovation and imitation:

$$\frac{\mathrm{d}\tilde{z}}{\mathrm{d}t} = Z(\dot{w}, \dot{w}^*, \alpha, \alpha^*) \tag{7.21}$$

The pattern of specialisation will not change through time if:[53]

$$\dot{w} - \dot{w}^* = \alpha - \alpha^* \tag{7.22}$$

Or, in other words, an 'imitative' country willing to increase its wage at the same rate as the 'innovative' country without 'de-specialising' has to sustain a rate of technological imitation (i.e. productivity improvement) equal to the rate of innovation of the 'leader'. Clearly, that same country may catch up if its rate of productivity growth is higher than that in the leading country (see Figure 7.4).[54] In each country, the maximum technically feasible rate of growth will be:

$$\dot{Y}_{\max} = \dot{\pi} + \dot{L} \tag{7.24}$$

and

$$\dot{Y}^*_{\max} = \dot{\pi}^* + \dot{L}^* \tag{7.25}$$

These are Harrod's 'natural' rates, with $\dot{\pi}$ equal to labour productivity growth and $\dot{L}$ equal to the rate of growth of labour supply. However, in the long run, each economy will be able to grow only at the maximum rate consistent with the balance of payment constraint: $Y_T{}^*$.[55]

Differentiating equation (7.11) with respect to time, we get:[56]

$$\dot{Y}_T - \dot{Y}^*_T = T(\dot{w}, \dot{w}^*, \alpha, \alpha^*, \mathrm{d}r/\mathrm{d}t) \tag{7.26}$$

where $\dot{Y}_T$ and $\dot{Y}^*_T$ stand for these maximum growth rates and $\mathrm{d}r/\mathrm{d}t$ stands for the change in the set of innovative commodities. The exports of the two countries are a function of the patterns of specialisation within the Ricardian commodities and of the net flow of innovative commodities.[57]

In the extreme case where B is specialised in all the Ricardian commodities with very sticky baskets of consumptions, the function is reduced to:

$$\dot{Y}_T - \dot{Y}^*_T = T\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right) \tag{7.28}$$

Equation (7.26) shows that convergence or divergence in the rates of growth compatible with the trade-balance constraint is essentially a function of the relative rate of productivity growth and the relative rate of product innovation and imitation.

Note that equation (7.26) does *not* show the *actual* rates of growth in each economy, but only the *relative* rates in A and B, consistent with the foreign accounts.

We may now consider the extreme (but not entirely implausible) case in which the international system is economically 'hierarchical': the endogenously generated growth of the leader (country A) is of paramount importance in determining the world growth rate. Suppose that the growth in A is essentially based on the flow of new products and new market opportunities (i.e. 'autonomous' investment undertaken in A). The international system can then be closed by:

$$\dot{Y} = \lambda\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right) \tag{7.29}$$

This crude over-simplification accounts for a fundamental Schumpeterian property of the dynamics of the international system, namely the role of innovations in the form of new product development and the associated autonomous investment, undertaken by the technological leader(s), as well as – in a more realistic formulation – imitators, as an *engine of growth*. This is the case, because such new product innovations expand export possibilities, while at the same time compensating for them with higher levels of endogenously generated demand, higher incomes and thus higher levels of imports. Purely productivity-increasing innovations, on the other hand, increase the *possibility* of growth of the international system, but at the same time might not generate an aggregate demand sufficient to achieve the notionally possible rate of growth.[58]

The model allows one to define a series of dynamic trade-offs. Particularly important is the dynamic property which states that, for any given rate of growth consistent with the balance of payment constraint, the higher the rate of product innovation in country A, the higher its relative wage growth (in other words, country A can afford to lose Ricardian commodities to country B); conversely, the higher the rate of imitation in B, the higher its rate of wage growth. The same argument can be repeated allowing the rates of growth to vary for some given rates of increase in wages.

Moreover, the model clarifies the difference between 'stationary' adjustment processes (i.e. holding technology constant) and 'dynamic' ones (i.e. related to technical change). A first stationary adjustment is based on the behavioural tendency at the microeconomic level towards minimum-cost/maximum-profit activities: at best, this induces a once-and-for-all increase in the short-term efficiency of the international location of productive activities.[59] This is what we have referred to as a *Ricardian adjustment process*. The other adjustment process at work, holding technology constant, refers to the property by which open economies 'pull' each other's demand via imports, while at the same time constraining each other's size and possibilities of growth via the need to balance the foreign accounts. We have called this a *Keynesian adjustment process*.

Certainly, even under conditions of no technical change, the system could undergo quantitative expansion by means of expanding investment and capital accumulation. In reality, however, growth is intimately interlinked with technical change. It is technical change which is of paramount importance in shaping the inner dynamism of the international system by (a) expanding the possibilities of growth; (b) *stimulating* that same growth via new or expanding international markets; and (c) continuously redistributing the relative possibilities of growth between countries.

In other words, technical change provides a *transforming* and *expanding* universe within whose boundaries 'stationary' adjustment processes take place at each given point in time.

In an open economy, the *relative* rates of innovation and imitation also define the moving thread of stimuli and constraints that each economy faces, thus determining also the relative dynamics of interdependent systems. In particular, if the relatively fast technological innovator fails to fill the 'Keynesian gap' between maximum and effective growth rates, the burden of adjustment will fall upon the 'slower innovator' who will have to adjust income growth to the foreign-balance constraint. This will also lower the growth possibilities of the fast innovator, who will, in turn, tighten the foreign-balance constraint of the slower innovator even further. The overall net result might even be a *lower* rate of growth of income than would have occurred without the new technologies, and a lower level of employment.

Whenever the 'slow' economy fails to increase its rate of technological progress, there appear to be three alternative results: (a) the country with the highest innovation speed is ready to finance the trade deficit of its partner(s); (b) protectionist barriers are erected by the slow-innovation country; and (c) the slow country is ready to accept lower rates of growth of its real wages in the hope that Ricardian processes of specialisation, jointly with favourable price elasticities of exports and imports, will neutralise, at least for some time, the increasing technology gap.

In open economies, technical change has the dual property of being labour-saving (in the simplest sense that it decreases the labour input requirements per unit of output), and at the same time competitiveness-increasing. This may determine a quite narrow growth path between the need to satisfy the foreign account and its effect upon domestic employment. Boyer and Petit (1980) describe this property with the metaphor of Scylla and Charibde. An increase in the relative rate of productivity growth of any one country presents a greater potential for growth for that same country, which, however, may not be entirely exploited by the endogenous creation of aggregate demand stemming from the augmented foreign competitiveness. On the other hand, a failure in innovating and thus, also, in increasing productivity, bears as a consequence the tightening of the foreign-balance constraint which will reduce growth possibilities.

The nature of the international equilibrium which is actually reached depends on the international distribution of the burden of adjusting foreign account imbalances and on the actual history of these adjustments. We can compare these international interdependence conditions with the properties of a tandem. *A priori*, there is an infinite range of velocities at which two or more people bicycling on a tandem can go. The interdependence between the cycling speed of each person, however, is rigidly fixed. It is relatively difficult to change velocity, especially to accelerate, unless there is a high level of coordination between them with respect to both effort and timing. Lacking such coordination, either the strongest cyclist must be powerful enough to pull the other(s) at the velocity he/she desires, or the velocity of the tandem will adjust close to that of the weakest one. The analogy also appears to be quite adequate in that the condition of international interdependence has often been fulfilled throughout the history of capitalist economies by means of the dominant position of one country which dictated the pace, and the rules of the game of international patterns of growth (cf. Mistral, 1982).

However, unlike the tandem analogy, where the distance between the partners is fixed, in the international system one or more economies may well fall behind or cluster nearer to each other, through patterns of divergence or convergence, as discussed above.

On a theoretical level, the approach suggested here presents some analogy with the family of models following on from Kaldor and Thirlwall, whereby the long-term rate of growth of each economy is determined by that maximum rate consistent with the balance of payment constraint.[60] The joint outcome of both 'stationary' adjustments and technical change could lead to the 'synthetic' formula (as in Thirlwall, 1980) expressing the dynamic foreign-trade multiplier:

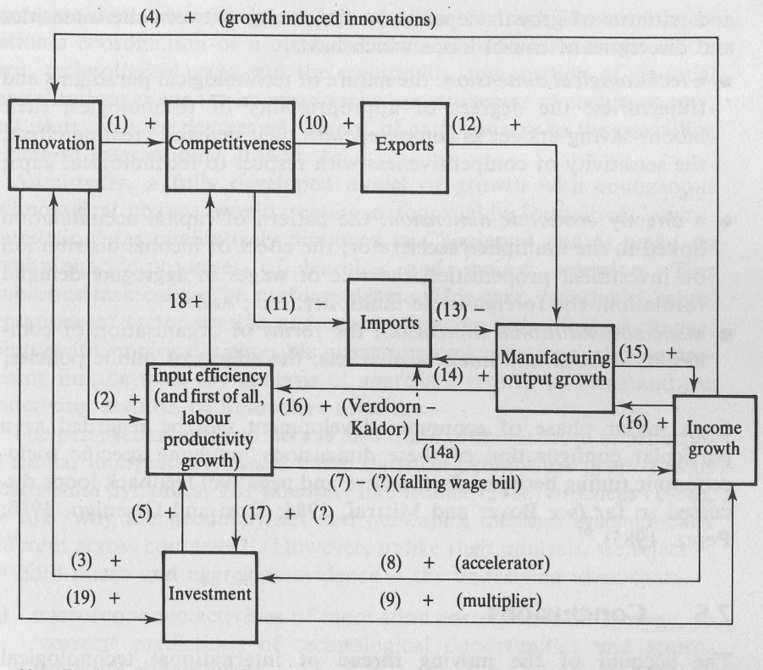
$$\dot{Y}_B = \frac{x_t}{Y_m} \tag{7.30}$$

where $\dot{Y}_B$ is the rate of growth of income, x_t is the rate of export growth and Y_m is the income elasticity for imports. However, the foregoing analysis implies that this is likely to be an approximate, albeit sometimes empirically robust, historical regularity.

A summary of the main causal chains, linking innovation and income growth, are depicted in Figure 7.6. Some of these links depend on the nature of technological trajectories and on the direction and intensity of the positive feedbacks between growth and technical change (see the links 1–6 and 19 in Figure 7.6). We could call this set of links the *technological 'regime'*.

Some other links relate to the effects of innovation upon competitiveness (see links 1, 10–13 and 18). We may call this set of relationships *the regime of insertion in the world economy* (see Mistral, 1985). Yet another set of links refers to the relationship between the tradeable and the non-tradeable sectors of the economy (the former being approximated here by manufacturing) (see links 15 and 16 in Figure 7.6). In a way, this is an expression for both the degree of openness of an economy and the degree to which its growth is based on the productivity of tradeable commodities.

One last set of relations highlights the *regime of macroeconomic*



Note: The (+) and (−) signs stand for the likely direction of the effect

Figure 7.6 The links between innovation, competitiveness and income growth: an illustration

demand formation (see link 19), which overlaps with the nature of the 'technological regime' (see links 7–9, 14a and 17 in Figure 7.6).

The Kaldor–Thirlwall formula is a synthetic formulation of links 12–16. On the grounds of our earlier discussion, we can predict that it presents an adequate representation of international differences in growth patterns, whenever both the technological regimes and the regimes of macroeconomic demand formation are stable through time, when they are relatively similar across countries, and when the institutional set-ups and policies are rather similar (so that the role of non-tradeables in each economy, i.e. links 15 and 16, follow similar patterns). One can see that these conditions broadly correspond to the period of high growth following the Second World War.

In general, however, the relationship between the innovative process and patterns of growth depends on the *tuning* between the intensities and directions of causal loops which have:

- a *technological dimension*: the nature of technological paradigms and trajectories; the degrees of appropriability of technologies; their labour-saving impact as compared with their demand creating effect; the sensitivity of competitiveness with respect to technological gaps, etc.;
- a directly *economic dimension*: the pattern of capital accumulation linked to the multiplier/accelerator; the effect of income distribution on investment propensities; the role of wages in aggregate demand formation; the foreign-trade multiplier, etc.; and
- a *social/institutional dimension*: the forms of organisation of commodity, labour and financial markets; the effects of public policies, etc.

Each major phase of economic development can be regarded as a particular configuration of these dimensions involving specific socio-economic tuning between the (positive and negative) feedback loops discussed so far (see Boyer and Mistral, 1984; Dosi and Orsenigo, 1988; Perez, 1985).[61]

7.5 Conclusions

The account of the moving thread of international technological gaps/leads between countries and the strong interdependence condition brought about by the foreign-balance constraint brings some important conclusions to the forefront.

First, the importance of the fact that each economy is 'open' lies in the link between technological dynamism, competitiveness, dynamism of demand patterns and accumulation rather than in a problem of short-term efficient allocation of given resources. Thus, whereas Ricardian adjustment processes (as defined above) are always at work, checking the (varying degrees of) allocative efficiency of the international system, the main impetus to international growth stems from the creation of new markets and new opportunities of accumulation, and the tendency toward increasing efficiency of used inputs.

Second, the model sketched in the first part of this chapter defines the conditions of international convergence/divergence in income and wages as ultimately dependent on convergence/divergence in technological levels and innovative capabilities.

Third, within interdependent economies, each characterised by some of the technological features described in Chapters 4 and 5, the satisfactory outcome of Keynesian processes of reciprocal adjustment in

aggregate demand is likely to depend either on high levels of international coordination or a highly hierarchical international system. In turn, technological gaps and the commodity composition of national specialisations shape the international competitiveness of each economy, and, thus, also the degrees of 'fitness' of each country to the prevailing regime of international growth.

Admittedly, a fully developed model of growth with endogenous technological change would require a thoroughly formalised 'micro-foundation' (as qualitatively discussed in Chapters 4 and 5) based on 'evolutionary' processes of learning and market selection. This ambitious task cannot be performed here. However, 'synthetic' representations of sector-specific and country-specific technological change, jointly with empirically plausible macroeconomic relations, allow a promising link between the analysis of aggregate growth patterns and the underlying features of innovative activities.

The perspective outlined here is also quite different from approaches to similar interpretative issues based on some equilibrium properties of steady-state dynamics. For example, like Romer (1986) or Lucas (1988), we ask 'why are productivities and per-capita incomes systematically different across countries?'. However, unlike their analysis, we reject – on both micro and aggregate evidence – the underlying ideas that:

(a) microeconomic activities of innovation correspond, on average, to 'correct' predictions of technological opportunities and appropriability conditions;
(b) individual agents are identical in their capabilities of accessing and exploiting public information and human resources;
(c) market-clearing conditions intertemporally hold.

In our view, departing from these assumptions entails a more fruitful possibility of joining microeconomic analysis of the patterns of technical change with nowadays 'old-fashioned' (Keynesian–Kaldorian) accounts of aggregate consistency conditions in the growth process. So – we suggest – balance-of-payments constraints, differentiated propensities to invest, diverse labour productivities, below-full-employment rates of growth and diverse rates of innovation/imitation, may all be deeply linked with 'disequilibrium' and country-specific characteristics of technological and organisational change.

The other side of the coin is, of course, that such a perspective, no matter how empirically plausible, has – as we have probably illustrated at length in this chapter – a significant theoretical price: formal modelling can only provide some sort of abacus on a few broad macro relations, without clean 'prediction' or elegant theorems. It highlights, however, the strong interactions of technological change, growth and trade patterns and the need for presenting, despite the complexity, a unified account of the microeconomics of innovation, observed patterns of trade, and the growth process.

Notes

1. Exceptions are Pasinetti (1981) and Nelson and Winter (1982). Other models which bear some similarities to the approach suggested here are Giovannetti (1985), Thirlwall and Vines (1983), Blecker (1985). More generally, what is argued here shows several similarities with the Kaldorian analysis of international growth patterns (see Kaldor, 1966, 1980). The Nelson–Winter model does not explicitly account for international trade. However, as should be clear from the earlier discussion (cf. Chapter 4), an evolutionary microstructure is precisely what is behind our synthetic representation of the determinants of growth patterns in the model that follows.
2. The reader should note that this definition has nothing in common with the 'Ricardian goods' sometimes found in trade literature: an improper name for commodities traded on the grounds of differential endowments of natural resources.
3. Dornbush, Fisher and Samuelson (1977) p. 823.
4. Note that each commodity z has its own specific machine. In equations (7.7)–(7.10) which follow, Pk_i, Ck_i, etc., are the equivalent in a discrete representation of $Pk(z)$, $Ck(z)$, etc., on the continuum.
5. That is Ck_iPk_i/P_i and $C^*k_iP^*k_i/P_i^*$ respectively.
6. The economic meaning of $h_i = h_i^*$ is simply that the relative backwardness or lead in machine manufacturing and machine product-technology is proportional to the backwardness/lead in the manufacturing of the final product. Making use of (7.5), (7.6), (7.7) and (7.8), the equality of capital/output ratios can be written as:
$$\frac{C_{ki}l_{ki}w}{(C_{ki}l_{ki}w)(1+r)+wa_i} = \frac{C_{ki}^*l_{ki}^*w^*}{(C_{ki}^*l_{ki}^*w^*)(1+r)+w^*a_i^*}$$
Rearranging and simplifying we get
$$\frac{C_{ki}l_{ki}}{C_{ki}^*l_{ki}} = \frac{a_i}{a_i^*} \qquad (7.10)$$
7. On these first two points cf. Thirlwall (1979) and (1980).
8. In a two-country model the imports of one country are obviously the exports of the other country.
9. The formulation in equation (7.11) still assumes, for convenience, homotheticity within each country. *A fortiori*, the argument that follows will apply to strictly non-homothetic demand functions.
10. In this model national and domestic incomes are identical.
11. The angle between the s-line and the w^*-axis is equal to w/w^* and to A $(\bar{z}_0)$.
12. The angle between the TB-line and the Y^*-axis is equal to Y/Y^* and $\psi^*(\bar{z})/\psi(\bar{z})$. Note that all the variables are taken to be measured in some real quantity, however mysterious that is. In particular, problems arise with regard to whether income and wages of each country are measured in terms of the commodity basket it produces or the basket it demands. Moreover, when we allow specialisation to change, both output baskets and relative prices must change. Facing all these ambiguities, we shall none the less overlook any index-number problem, confident to be forgiven at least by all those economists who keep using aggregate production functions despite a much more devastating critique of the possibility of measuring aggregate capital.

13. In the more complex case of 7.13.1 and 7.14.1 employment is still linear in Y/w, through the income distribution coefficient $(1/s)$.
14. Each average productivity is a weighted average of the $(1/a_i)$ and $(1/a_i^*)$ between 0 and z and between $\bar{z}$ and 1, respectively.
15. There is an ambiguity in this statement in that an index-number problem is unavoidable; however, cf note 14.
16. The simplest hypothesis which guarantees the feasibility of the new wage pairs (i.e. that they remain equal or in some proportion to the average productivity of each economic system) is to assume that the ranking of the $a(z)$s, in A, and the $a^*(z)$s, in B, are both monotonic in $A(z)$, so that the average productivity of each economic system increases as the number of produced commodities decreases. As already mentioned, we basically overlook any index-number problem involved in the changes of output mix.
17. Relaxing these simplifying hypotheses, the set of acceptable specialisations is defined within the area $AXZB$. Our discussion will generally stick to the simpler case, which also highlights the properties of more complex systems.
18. Note that this area also includes the points that are 'technically' in equilibrium but may be socially unacceptable.
19. The reader may visualise the case by thinking of the recent Japanese experience; cf. Thirlwall (1979) for an empirical argument about the Japanese case along similar lines.
20. In other words, an absolute fall in wages and incomes in the 'slow' country is by no means a necessary consequence since there is no shrinking of the 'outward' boundaries of its equilibrium possibilities. It may, none the less, happen. See below.
21. For a discussion of this feature of national economic systems, see Chapters 3 and 4.
22. Note that this is often the case in developing countries.
23. The reader must be reminded again that the model thus far is concerned with the constraints to domestic income and employment. For all rates of activity below full employment a reduction in wages will also relax the foreign-balance constraint. However, this does not imply that it will yield an improvement in the actual levels of income and employment. Since wages are a crucial component of domestic aggregate demand, the opposite may well occur. See below.
24. Cf. J. Robinson (1974).
25. These conditions somewhat resemble Prebisch's analysis of underdeveloped economies; cf. Prebisch (1950). More generally on the role of income elasticities, see Thirlwall (1980).
26. This is not unlikely: cf. Chapter 5, on the capital-saving nature of technical progress.
27. We have still to accept the possibility of widespread 'reswitching of commodities' for this statement to rigorously apply.

28. The reader should remember that the model is not necessarily confined to a 'North–South' framework but is meant to apply to differences between developed countries as well. In a sense, all countries could be placed on a continuum according to the size of their technological gap vis-à-vis the country showing the highest average technological levels.
19. We are focussing here only on the set of final goods. The reader might have noticed, however, that the brief discussion above on capital-goods only produced by country A implicitly assumed that all capital goods are innovative commodities.
30. One may notice some significant resemblance with the role of the United States vis-à-vis Europe and Japan in the post-War period.
31. Cf. Emmanuel (1969). A critical discussion can be found in Evans (1980).
32. We assume that all new products are also immediately consumed by B. Even if this does not occur, however, the property still holds since the relative intensity of B-product in A-income will necessarily decrease and so the foreign-balance constraint for A will be relaxed.
33. Remember that the absolute levels of wages in each country must bear a relationship to the average productivity of the same economy for any given pattern of specialisation. This is also proportional to the Euclidean distance between any point in the income–wage possibility set and the origin along a given f or f^* line.
34. We discussed it at length in Dosi (1984).
35. Cf. Thirlwall (1980). The case characterised only by product innovation and imitation exhibits some features similar to Krugman's model (cf. Krugman, 1979). However, there are some aberrant properties of the latter stemming from its (unnecessary) choice of a general equilibrium framework. For example, a simple increase in the labour supply in the innovating country worsens its income and terms-of-trade. Moreover, were we allowing process innovations in such a model they would have a detrimental effect on the innovating country (cf. Cole, 1980). These unlikely properties stem from the fact that a general equilibrium set-up allows only a definition of prices and terms-of-trade in relation to relative scarcities under a requirement, *ex-hypothesi*, of market clearing. We hope we have avoided all these drawbacks here, by avoiding a conceptual framework which makes dynamics very difficult to represent.
36. See also similar models developed by Krugman (1979) and more recently by Grossman and Helpman (1990a,b).
37. The analysis that follows will continue to deal with real magnitude despite all index-number ambiguities.
38. By definition, $Y = R + W$ (i.e. the total income is made of wages (W) and profits (R)) so that we can writc the total consumption as $c_k(Y - W) + c_w W$. If $c_w = 1$ then the expression equals $c_k Y + (1 - c_k)W$.
39. We stick to the simpler hypothesis that all capital goods are domestically produced.
40. The equations are now (7.3), (7.12), (7.13.1), (7.14.1) and (7.17) with $\bar{z}$, w, w^*, N, N^*, Y, Y^* as unknowns and I and I^* as exogenous variables.
41. We discuss some of these issues in Dosi and Orsenigo (1986). See also Silverberg (1985).
42. It may well happen that a decrease in wages leads to a decrease in income in the domestic economy, let alone the other one. This can be seen by differentiating Y with respect to w in equation (7.16). Calling G the

denominator of the multiplier we obtain:

$$\mathrm{d}Y/\mathrm{d}w = \frac{1}{G}\left\{\left[\frac{1}{G}\left(-\mathrm{d}\psi(\,)/\mathrm{d}w + \frac{1-c_k}{\pi^*}\right)\right]\right.$$
$$\left.(\psi^*(\,)\cdot Y^* + I) + Y^*(\mathrm{d}\psi^*(\,)/\mathrm{d}w)\right\} \qquad (7.8)$$

The expression within the square brackets can be positive, so that whenever the relative proportion of exports to investments as an 'engine of demand' is low, the increase in export may not compensate for the fall in the domestic multiplier if the elasticities of exports and imports to changing costs are low. Moreover, a decrease in wages (which can be taken as equivalent in any respect to a devaluation) certainly depresses income of the partner(s). One can see here how the endogenous adjustment process may lead to beggar-my-neighbour results and depress the overall rates of macroeconomic activity. Clearly, a full macroeconomic model should also account for the effect of changing income distribution upon the propensity to invest. This is yet another complex issue. Here we are simply forced to state, without any proof, that – even after allowing the effects of changing distributive shares upon the rate of investment – one may not find a sufficient compensating stimulus for the rates of macroeconomic activities. On this issue, see also Sylos Labini (1984), Dosi and Orsenigo (1988), Boyer and Mistral (1983), Cimoli (1988).
43. For a discussion, see Dosi and Orsenigo (1988).
44. In a more complex framework with input/output interdependencies we could define these ideal types of innovation as (a) innovations which increase labour productivity in any one vertically integrated sector without any change in the nature of the outputs and of intermediate and capital inputs; and, (b) innovations which create new vertically integrated sectors, without affecting the coefficients of the existing ones. On the concept of vertically integrated sectors cf. Pasinetti (1981).
45. This can be seen by differentiating equation (7.16) with respect to (π).
46. Cf. Dosi (1984), and Dosi and Orsenigo (1988).
47. On the sequential nature of 'Keynesian' adjustment processes, cf. Pasinetti (1974).
48. The conditions of dynamic stability of such a system are discussed in Dosi and Orsenigo (1988).
49. More precisely the actual growth of the partner economy will fall if the innovative one does not fully exploit its own expanded growth possibilities, compensating with higher income levels for a lower import propensity and higher export propensity.
50. In Dosi (1982a) we illustrate one such case. Note that this argument is consistent with the evidence of no significant impact of productivity growth (net of the effect of foreign competitiveness) upon domestic growth. See Boyer and Petit (1980).
51. For this to happen (neglecting second order conditions) we must have $\psi \cdot \Delta Y + Y \cdot \Delta\psi > 0$. This will generally be satisfied, since the growth in income is not only due to the improved foreign-trade multiplier, but also to the domestic increase in autonomous investment.
52. This last effect on B-income will not apply only if the introduction of the new commodity significantly changes the income intensity of B-exports as

compared to B-imports. If this change is large enough the worsening 'quality' of B-specialisations will more than compensate for the positive effect of higher A-growth rates upon B-exports.

53. Rewriting equation (7.4). In its dynamic form, we get

$$A(\tilde{z}(t), t) = w(t)/w^*(t)$$

Differentiating with respect to time

$$\frac{1}{a}\left[\frac{\partial a}{\partial t} + \frac{\partial a}{\partial \tilde{z}} \cdot \frac{d\tilde{z}}{dt}\right] - \frac{1}{a^*}\left[\frac{\partial a^*}{\partial t} + \frac{\partial a^*}{\partial \tilde{z}} \cdot \frac{d\tilde{z}}{dt}\right] = \frac{1}{w} \cdot \frac{dw}{dt} \Big/ \frac{1}{w^*}\frac{dw^*}{dt} \qquad \mathbf{(7.23)}$$

Rearranging, one sees that for $d\tilde{z}/dt = 0$, $\dot{\alpha} - \dot{\alpha}^* = \dot{w} - \dot{w}^*$ where α stands for $1/a\ (\partial a/\partial t)$, etc., and, analogously the dots stand for the rates of change. Moreover, note that we assume here 'balanced' productivity growth across all Ricardian commodities. This is only a simplifying device: the essence of the argument also applies to all cases of 'unbalanced' patterns of technical change.

54. Think of post-War productivity trends in Western Europe and Japan as compared with the United States.
55. Remember that throughout our discussion we are neglecting the possibility of international capital flows so that the balance of payment is identical to the trade balance.
56. Differentiating equation (7.11), and also accounting for the effect of innovative commodities (r) upon import propensities, we obtain:

$$1/Y(dY/dt) - 1/Y^*(dY^*/dt) = 1/\psi\left[\frac{\partial \psi}{\partial \tilde{z}} \cdot \frac{d\tilde{z}}{dt} + \frac{\partial \psi}{\partial r} \cdot \frac{dr}{dt}\right] - $$
$$+ 1/\psi^*\left[\frac{\partial \psi^*}{\partial \tilde{z}} \cdot \frac{d\tilde{z}}{dt} + \frac{\partial \psi^*}{\partial r} \cdot \frac{dr}{dt}\right] \qquad \mathbf{(7.27)}$$

By appropriately rearranging equation (7.23), one gets $d\tilde{z}/dt$ as a function of α, α^*, $\dot{w}$, $\dot{w}^*$.

57. Net of product imitation by B.
58. They might not, although clearly sometimes they do: this occurs essentially when productivity-increasing innovations are associated with the accelera-tion of the diffusion of new product innovations. Think of the relation between the fall in the relative price and diffusion of electronic products. The important point, however, is that in all these cases productivity growth and product innovation are part of the same innovative process.
59. See Pasinetti (1981).
60. Cf. Thirlwall (1980) which presents a thorough and convincing discussion of the issue. See also Kaldor (1970), Kennedy and Thirlwall (1979).
61. 'Socio-economic tuning' here is the equivalent of the French 'regulation', meaning those forms of economic organisation, rules of behaviour and institutions which 'channel the long term dynamics ... of an economy during an historical period for a given society' (Boyer and Mistral, 1984, p. 9). For more detailed discussion, see Dosi and Orsenigo (1988).