Chapter 13
International Trade and Growth: Comparative Statics

13.1 Introduction

At the cost of some simplification, the causes of growth are traditionally classified in two categories: increase in factor endowments and technical progress. Many believe that such a classification is artificial, for in the real world these two causes are not separable: for example, the increase in the stock of capital often consists in the purchase of new machines rather than of machines identical to those already owned. Since the new machines contain the latest technological improvements ("embodied" technical progress), it becomes impossible to distinguish the increase in the capital stock from technical progress.

It should also be noted that in traditional theory technical progress is *exogenous*, in the sense that technological improvements fall on the economy like manna from heaven. Technical progress, however, usually derives from activities directed at procuring it (for example R&D: Research and Development), hence it is normally *endogenous*.

We refer the reader to the textbooks on economic growth for a detailed examination of these problems and we maintain the traditional distinction for simplicity's sake, also assuming that technical progress is exogenous and of the "disembodied" type. More sophisticated forms of technological change will be examined in Chap. 15.

The theoretical analysis of the relations between growth and international trade was initially directed to the examination of the effects of the various forms of growth on international trade, in particular on the volume and pattern of trade, on the terms of trade, and on welfare. In this analysis—which is essentially of a comparative-static nature and usually adopts the assumptions of first-degree homogeneous production functions and of no factor intensity reversal—growth and its causes are considered as given and their impact on international trade is explored.

This is an inherently incomplete or partial analysis, as it examines solely one aspect of the problem: the increase in the stock of capital, for example, is not a windfall but depends on investment; besides, international trade can influence

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growth. Therefore, in a more general setting, one must consider the interrelationship between trade and growth, as these influence each other. The analysis of these problems requires the use of dynamic models, which will be briefly examined in the next chapter. Besides, as stated above, the sources of growth, and in particular technological progress, cannot be taken as exogenous. The relations between the theory of endogenous growth and international trade will be examined in Chap. 15.

It is as well to inform the reader that we shall not deal with the relations between international trade and economic development (as distinct from growth), that is, with the specific problems arising when one considers the role of international trade in the development of less-developed countries. This is a topic of great importance but cannot be adequately dealt with here, as it pertains more to (and in any case requires the knowledge of) development economics. Part of the material examined in this and in other chapters (as, for example, the infant industry argument illustrated in Sect. 11.2, and some of the "new" theories of international trade examined in Part III) could of course be relevant to issues of economic development, as shown, for example, by Findlay (1984), but for the reasons stated we do not examine these aspects.

13.2 The Effects of Growth on the Volume of Trade

The study of these effects requires a preliminary examination of the consumption and production effects of growth, which we shall perform following the classification of Johnson (1955, 1959); see also Chacholiades (1978), Corden (1971b), Ghosh (1984), Takayama (1972), Woodland (1982).

13.2.1 Consumption Effects

As regards the *consumption effects*, the question of interest is whether growth, *at unchanged relative price* of the commodities (terms of trade), will increase the demand for the importable[1] more than proportionally to, in the same proportion as, or less than proportionally to, the increase in national income (measured in terms of either commodity, i.e. in real terms), that is, whether growth will make the country relatively less self-sufficient (more dependent on trade), neither more nor less dependent on trade, or relatively more self-sufficient. It is in fact clear that, if the demand for the importable increases more than proportionally to the increase

[1]The importable is, as usual, the commodity for which there exists a domestic excess demand in the relevant price range; as we assume incomplete specialization, this commodity is also produced domestically.

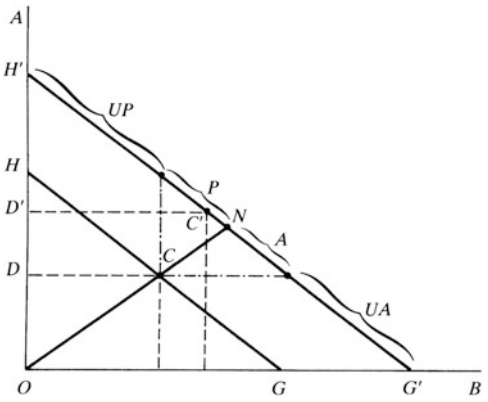

Fig. 13.1 Consumption effects of growth

in national income, this will tend— *ceteris paribus*, i.e. ignoring for the moment the production effects[2]—to increase international trade (in the sense of the share of imports in national income[3]) and vice versa in the opposite case. In the former case growth is defined as *pro-trade biased*, whilst it is called *anti-trade biased* in the opposite case and *neutral* in the case of equiproportional increases.

There are, in addition, the case of *ultra-pro-trade-biased* growth, in which the demand for the importable increases not only more than proportionally to the increase in national income, but also by a greater absolute amount, and the case of *ultra-anti-trade-biased* growth, in which the demand for the importable decreases when national income increases (this implies that we are in the presence of an inferior good).

The five cases listed above can be conveniently illustrated in terms of Fig. 13.1. The budget line or equal national income line (which we call *isoincome*) HG represents the value of the initial national income, and OH is the initial real national income in terms of commodity A (for isoincome lines see Sect. 13.2.3). The initial consumption point is C, so that the consumption of the importable is OD. Growth shifts the isoincome line (at constant prices) in parallel upwards to $H'G'$, and the proportional increase in income is $H'H/OH$. If, for example, the new consumption point is C', the proportional increase in the demand for the importable is $D'D/OD$. As $D'D/OD > H'H/OH$, growth is pro-trade biased (P). It is possible to check graphically that, if the new consumption point falls:

[2]It should be pointed out that, in the case of *complete specialization,* the imported commodity is not produced at home, so that there are no production effects and the effects of growth coincide with the consumption effects.

[3]Since in the context of the pure theory of international trade the value of imports equals the value of exports, it makes no difference whether this share is measured in terms of imports or exports. Given the relative price, once the effects on the excess demand for A (demand for imports) have been determined, Walras' law (see Sect. 3.3) immediately allows us to determine the effects on the excess supply of B (supply of exports).

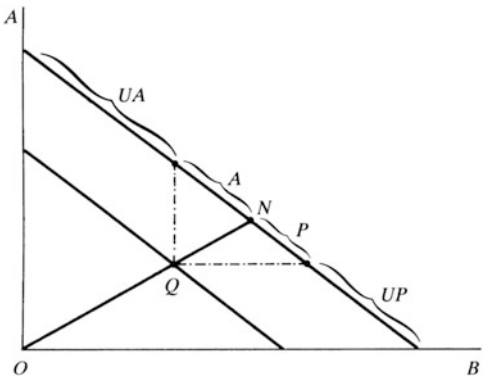

Fig. 13.2 Production effects of growth

1. In segment *UP* (ultra-pro-trade), the absolute increase in the demand for the importable is greater than the absolute increase in national income (this, of course, implies that the other good is inferior);
2. In segment *P* (pro-trade), the proportional increase in the demand for the importable is greater than the proportional increase in national income;
3. At point *N* (neutral), the proportional increases in the two variables are equal;
4. In segment *A* (anti-trade), the proportional increase in the demand for the importable is smaller than the proportional increase in national income;
5. In segment *UA* (ultra-anti-trade), the demand for the importable decreases in absolute terms (this, of course, implies that it is an inferior good).

13.2.2 Production Effects

If we now consider the *production effects*, we can give an analogous classification on the basis of the relations between the variation in the domestic output of the importable and the increase in national income, at unchanged relative price of the commodities. In this context, the degree of self-sufficiency is positively related to the increase in the domestic output of the importable. If, for example, this output increases more than proportionally to the increases in national income, the country will—*ceteris paribus*—become more self-sufficient (less dependent on trade): growth is anti-trade biased as regards its production effects. In Fig. 13.2, point *Q* represents the initial output bundle; with a reasoning similar to that used in relation to Fig. 13.1 we can see that if the point representing the new output bundle falls in segment *UA*, the absolute increase in the domestic output of the importable is greater than the absolute increase in national income, so that growth is ultra-anti-trade-biased, and so on for segments *A*, *P*, *UP* and for point *N*.

13.2.3 A Reformulation in Terms of Elasticities: The Total Effect

What has been stated in terms of relations between proportional increases can be reformulated in terms of domestic demand and supply income-elasticities. The income elasticity of the domestic demand for the importable is defined as the ratio between the proportional increase in this demand and the proportional increase in national income, that is

$$\eta_{dY} = \frac{\Delta A^D / A^D}{\Delta Y / Y}, \tag{13.1}$$

that is, in terms of Fig. 13.1

$$\eta_{dY} = \frac{D'D/OD}{H'H/OH} = \frac{D'D/OD}{G'G/OG}.$$

It can be easily checked that this elasticity can also be written as the ratio between the marginal propensity μ_{dY} and the average propensity α_{dY} to consume commodity A; in fact

$$\eta_{dY} = \frac{\Delta A^D / \Delta Y}{A^D / Y} = \frac{\mu_{dY}}{\alpha_{dY}}. \tag{13.2}$$

Given these definitions, the consumption effects of growth will be pro-trade-biased , neutral, anti-trade-biased according to whether $\eta_{dY} \gtreqless 1$; the ultra-pro-trade and ultra-anti-trade cases occur when $\mu_{dY} > 1$ and $\mu_{dY} < 0$ respectively.

As regards the production effects, we can define an elasticity of domestic supply (production) of the importable as

$$\eta_{sY} = \frac{\Delta A^S / A^S}{\Delta Y / Y} = \frac{\Delta A^S / \Delta Y}{A^S / Y} = \frac{\mu_{sY}}{\alpha_{sY}}, \tag{13.3}$$

where μ_{sY} and α_{sY} are the marginal and average propensity to produce commodity A. The production effects of growth will be pro-trade-biased, neutral, anti-trade-biased according to whether $\eta_{sY} \lesseqgtr 1$; the ultra-pro-trade and ultra-anti-trade cases occur when $\mu_{sY} < 0$ and $\mu_{sY} > 1$ respectively.

The effects of growth on the demand for imports (this demand must not be confused with the demand for importables: the two coincide only in the case of complete specialization, whilst in the normal case of incomplete specialization the demand for imports equals the demand for the importable less the domestic production of this commodity) depend on the combination of the consumption and production effects. The result will be pro-trade-biased, neutral, or anti-trade-biased according to whether the demand for imports increases more than proportionally

Table 13.1 Classification of the effects of growth on trade by combining the consumption and production effects

	Consumption effect				
Production effect	Neutral	Pro-trade	Ultra-pro-trade	Anti-trade	Ultra-anti-trade
Neutral	N	P	P or UP	A or UA	UA
Pro-trade	P	P	P or UP	Not UP	UA
Ultra-pro-trade	P or UP	P or UP	UP	Not UA	All types possible
Anti-trade	A or UA	Not UP	Not UA	A or UA	UA
Ultra-anti-trade	UA	UA	All types possible	UA	UA

to, in the same proportion as, or less than proportionally to the increase in national income; it will be ultra-pro-trade-biased or ultra-anti-trade-biased when the increase in the demand for imports is greater than the absolute increase in income, or when this demand decreases as income increases.

The result can easily be determined when the consumption and production effects have the same bias. If, for example, they are both pro-trade-biased, the demand for imports will certainly increase: in fact, this means that, for the same (proportional) increase in income, the demand for the importable increases more than proportionally to the increase in its domestic production, so that the demand for imports must increase to make up the difference. Besides, this increase is proportionally greater than the increase in income. In fact, if we denote by g_d, g_s, g_m, g_Y the (proportional) growth rates of the demand for the importable, the domestic production of this, the demand for imports, and national income, respectively, then, in general (see Sect. 27.1),

$$g_m = g_Y + \frac{A^D}{A^D - A^S}(g_d - g_Y) - \frac{A^S}{A^D - A^S}(g_s - g_Y), \tag{13.4}$$

so that, in our case, $g_m > g_Y$ as $g_d > g_Y$ and $g_s < g_Y$. Unfortunately the results are less obvious when the consumption and production effects have an opposite bias. The results of all possible combinations are given in Table 13.1: for example, the result of a growth which has a pro-trade-biased production effect and a neutral consumption effect can be read off the intersection of the row labelled pro-trade and the column labelled neutral.

Most results are intuitively clear and are those occurring when both consumption and production effects have the same kind of bias or when one of the two effects has a certain bias whilst the other is neutral; these results can easily be checked by means of (13.4). It is similarly intuitive that the table is symmetric with respect to the diagonal: for example, the result of a pro-trade-biased production effect combined with an ultra-anti-trade-biased consumption effect is qualitatively the same as the

result of a pro-trade-biased consumption effect combined with an ultra-anti-trade-biased production effect.

Less intuitive is the fact that whilst an ultra-anti-trade-biased effect prevails on a pro-trade-biased effect (the result is an any case *UA*: see Table 13.1), on the contrary an ultra-pro-trade-biased effect does not prevail on an anti-trade-biased effect (the result is in any case not *UA*, so that a result *A* is also possible). To understand this asymmetry we must remind that imports are the excess demand for the importable, $A^D - A^S$. Now, in the case of a *UA* consumption effect combined with a *P* production effect, A^D decreases whilst A^S increases (though less than proportionally to the increases in income), so that $A^D - A^S$ certainly decreases (a *UA* result). Similarly, in the case of a *UA* production effect combined with a *P* consumption effect, A^S increases by more than the absolute increase in income and A^D also increases, but by less than the absolute increase in income; therefore A^D increases by less than A^S and the demand for imports $A^D - A^S$ decreases (a *UA* result).

On the contrary, in the case of a *UP* consumption effect combined with an *A* production effect, A^D increases by more than the absolute increase in income and A^S also increases, but by less than the absolute increase in income. It follows that the demand for imports $A^D - A^S$ certainly increases (so that the result cannot be *UA*), but we do not know whether it increases more or less than proportionally to the increase in income, so that the result might be *A*. Similarly in the case of a *UP* production effect combined with an *A* consumption effect, A^S decreases whilst A^D increases, but less than proportionally to the increase in income: the demand for imports $A^D - A^S$ certainly increases (and so the result cannot be *UA*), but we do not know whether it increases more or less than proportionally to the increase in income, so that the result might be *A*.

13.3 Growth and Terms of Trade: Immiserizing Growth

13.3.1 The Large Country and the Terms of Trade

We have so far assumed that the relative price of commodities (terms of trade) is given. This assumption is acceptable in the context of a small country model, where the changes in the country's demand for imports and supply of exports have negligible effects on the world market. But in the opposite case one must investigate the effects of the various types of growth on the terms of trade. For this purpose, it is necessary to determine the shifts of the offer curve of the growing country (country 1, say) due to the various types of growth. In Fig. 13.3 we have the initial offer curve (OG_1) and terms of trade (slope of *OR*); for the time being, we ignore curve OG_2. The initial equilibrium point is *E*. Since in all types of growth—except for the ultra-anti-trade-biased one—there is an increase in the demand for imports at unchanged terms of trade (and so in the supply of exports, given Walras' law: see

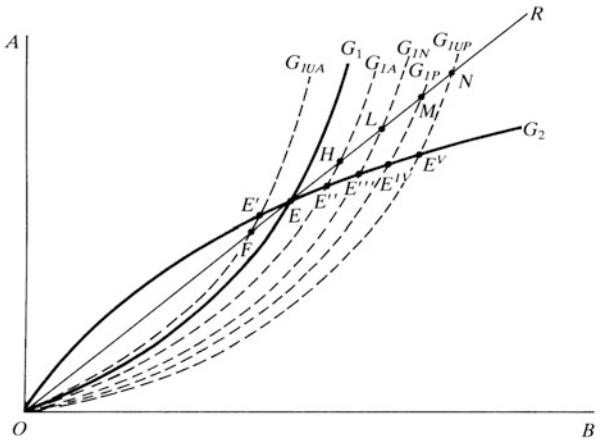

Fig. 13.3 Growth shifts the offer curve and changes the terms of trade

Chap. 3), the points on the terms-of-trade ray OR corresponding to the new offer curve will all be to the right of E, except for the UA case, in which the point will be to the left of E (lower imports and so lower exports) . The order of the points will be that indicated in Fig. 13.3, since the absolute increase in the demand for imports for a given increase in income is greater as growth is more favourable (or less unfavourable) to trade.

Since the reasoning can be repeated for any given terms of trade, if we imagine rotating ray OR we obtain the broken-line offer curves OG_{1UA}, OG_{1A}, and so on. In the case of a small country, OR would be given, and we would only have to consider points F, H, L, M, N, which illustrate the effects of growth on the volume of trade described in Sect. 13.2. In the case in which the growing country is not small, the shifts in its offer curve will influence the terms of trade. This can be verified by introducing the (given) offer curve of country 2, OG_2 and finding the intersection between this and country 1's new offer curve, so as to determine the new international equilibrium point. This will be E', or E'', etc., depending, as the case may be, on the type of growth actually occurring.

It can be seen from the figure that the terms of trade become worse and worse in all cases of growth (except in the UA case, in which they improve), the more favourable (or less unfavourable) to trade growth is. One only has to draw straight line segments from the origin to the various points E'', E''', etc. and verify that their slope (equal to the terms of trade p_B/p_A) gets smaller and smaller than the slope of OR (except for the slope of OE', which is greater).

This result can be explained in the following way: if we exclude UA growth, in all other cases country 1's demand for imports increases at the given terms of trade, so that an excess demand for A will arise in the world market (and, given Walras' law, there will be a correlative excess supply of B): this will cause a decrease in p_B and an increase in p_A, thus a decrease in p_B/p_A. As these forces grow more intense

the greater the excess demand for A and the excess supply of B in the world market, there will be a greater decrease in p_B/p_A the greater the excess demand and supply become. However, these price changes will put a brake on country 1's demand for A and supply of B, while at the same time stimulating country 2's supply of A and demand for B. This explains why in the new situation of equilibrium country 1's demand for imports of A and supply of exports of B will ultimately increase by less than the initial effect of growth: it is, in fact, sufficient to compare the coordinates of any one of the points $E'', \ldots, E^V$ with those of the corresponding equilibrium points $H, \ldots, N$.

In the case of *UA* growth, on the contrary, the results are quite the opposite: the initial decrease in country 1's demand for imports, etc., gives ultimately rise to an increase in p_B/p_A and so to a boost to that demand, etc.; thus at the new equilibrium point E', there will be an improvement in the terms of trade and a decrease in the volume of trade, which is, however, less intense than the initial decrease (point F).

It should be stressed that the analysis so far is valid in the case of normal offer curves: in the case of anomalous offer curves the results might be different, but we do not wish to burden our treatment with the examination of these, which the reader can in any case easily perform by way of the same technique. Instead it is important to mention the possible negative effects of growth on social welfare: this is the so-called immiserizing growth case.

13.3.2 Immiserizing Growth

Growth is called immiserizing when it reduces the welfare of the growing country. This possibility was first pointed out by Edgeworth (1894, pp. 40–42) and taken up again by Bhagwati (1958, 1973), who gave it its name, and other authors: see Bhagwati et al. (1998, chap. 29); Hatta (1984). On the relations between immiserizing growth and donor-enriching "recipient immiserizing" transfers see Bhagwati, Brecher, and Hatta, 1984.

This phenomenon involves the relations between growth, changes in the terms of trade, and changes in welfare. In general, as we have seen, growth can bring about either an improvement or a deterioration in the terms of trade. The deterioration in the terms of trade can, in turn, improve, leave unchanged, or cause a deterioration in social welfare. It follows that the deterioration in the terms of trade is a necessary, but not a sufficient condition for the decrease in social welfare. Let us now examine the case we are concerned with.

If we assume that the terms of trade deteriorate as a consequence of growth, the possibility of a decrease in social welfare is illustrated in Fig. 13.4, where TT is the initial transformation curve. Given the initial terms of trade represented by the slope of RR, the country produces at Q and consumes at E by trading $Q_B E_B$ of B (exports) for $Q_A E_A$ of A (imports), thus reaching the social indifference curve I. As a consequence of growth the transformation curve shifts to $T'T'$ and the terms of trade deteriorate (the slope of $R'R'$ is lower in absolute value than the slope

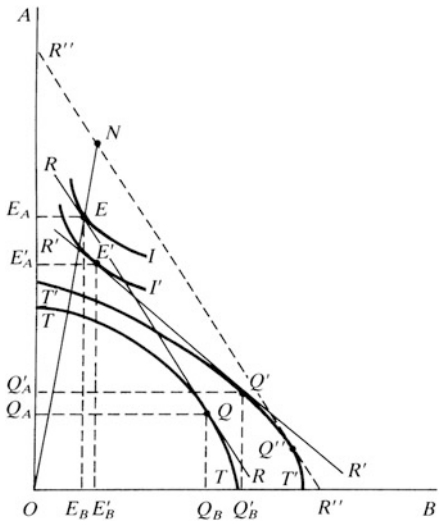

Fig. 13.4 Immiserizing growth

of RR). The country produces at Q' and consumes at E' by trading $Q'_B E'_B$ of B for $Q'_A E'_A$ (it is easy to see that $Q'_A E'_A < Q_A E_A$ and $Q'_B E'_B > Q_B E_B$, that is, the country obtains less imports in exchange for more exports). As E' is on the social indifference curve I', lower than I, social welfare has decreased.

It is interesting to ascertain which is the type of growth (according to the classification examined in the previous section) represented in Fig. 13.4. For this purpose we have to determine the consumption point and the production point along the $T'T'$ curve at unchanged terms of trade. By drawing a tangent to the $T'T'$ curve parallel to the RR straight line, i.e. $R''R''$, we find the production point Q'', which implies a lower output of A and a higher output of B with respect to Q'. Therefore, growth has ultra-pro-trade-biased production effects. As regards the consumption effect, the point of tangency between $R''R''$ and a social indifference curve may in general occur either to the left or to the right of N or even at N, so that in the absence of further information we cannot classify the consumption effect. However, if we exclude the possibility that A is an inferior good (thus excluding a UA consumption effect), then, on the basis of Table 13.1, we can conclude that the type of growth is certainly not UA. The same result is obtained if we observe, on the basis of Fig. 13.3, that the condition for the terms of trade to move against the growing country is that growth must not be UA.

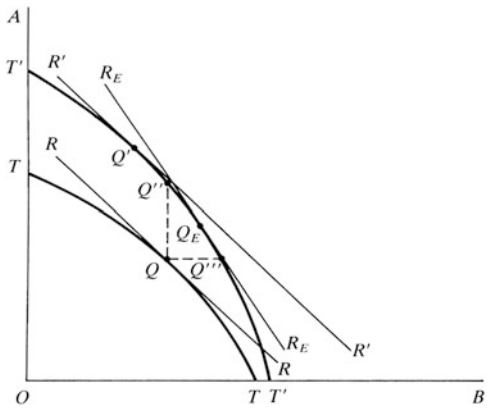

Fig. 13.5 Rybczynski's theorem and relative price of goods

13.4 Increase in Factor Endowments and International Trade: Rybczynski's Theorem

In this section we examine the effects of an increase in factor endowments; the effects of technical progress will be examined in the next section. More sophisticated forms of growth will be analysed in Chap. 15.

The point of departure for examining the effects of an increase in factor endowments is Rybczynski's theorem, (Rybczynski, 1955; see also McDermott, 1985) according to which the increase in the quantity of a factor (given the other) will cause an increase in the output of the commodity which is intensive in that factor and a decrease in the output of the other commodity, at unchanged commodity and factor prices.

The proof of this theorem has been given in Sect. 5.4. We now consider a trading open economy, where we must distinguish the small country case from the case in which the country is sufficiently large for its demands and supplies on the world market to influence the terms of trade.

Let us consider Fig. 13.5 (which reproduces Fig. 5.2) and assume, by way of example, that commodity A is the importable. We further assume, for simplicity, that no commodity is inferior, so that, when income increases, the demand for both A and B increases (each, of course, increases by less than income). In the passage from Q to Q', the output of commodity A has increased more than income whilst the output of B has decreased. It follows that, within the country: (a) the excess demand for A (demand for imports) decreases, as output has increased more than demand; (b) the excess supply of B (supply of exports) decreases, as output has decreased whilst demand has increased. Therefore, on the world market, at the given world relative price, there will be a decrease in both the demand for A and the supply of B.

It is at this point that the distinction between the small and the large country case becomes relevant. In the former case the terms of trade do not change, the country

will go on producing at Q' and we shall be in the presence of a case of *UA* growth, as the country's demand for imports (and supply of exports) have decreased.

In the latter case, the excess supply of A on the world market (due to the decrease in the country's demand for imports), and the correlative excess demand for B (due to the decrease in the country's supply of exports) will cause changes in world prices, since the excess supply of A will put a downward pressure on p_A and the excess demand for B an upward pressure on p_B; therefore the terms of trade p_B/p_A increase. This confirms the closed-economy result. Note that, since we have assumed A to be the importable, the terms of trade have improved.

An alternative way to arrive at the same results is to employ the analysis carried out in the previous sections. Since A is, assumedly, the importable, with reference to Fig. 13.2 we find that Q' lies in the *UA* stretch of the isoincome line, so that the increase in the amount of labour has given rise to a growth with *UA* production effects. It is therefore unnecessary to know the consumption effects: in fact, from Table 13.1 we know that a growth with *UA* production effects is globally *UA*, except for the case of *UP* consumption effects, which is, however, ruled out by the assumption of no inferior goods (*UP* consumption effects on A, in fact, imply a decrease in the consumption of B). As regards the change in the terms of trade of a large country, we know from Fig. 13.3 that a *UA* growth causes an increase in the relative price p_B/p_A, that is, an improvement in the terms of trade as A is the importable.

Let us now consider the case in which the importable is commodity B, maintaining the assumption that there are no inferior goods. When the production point shifts from Q to Q', the consequences for the country will be: (a) the excess supply of A (supply of exports) increases, since its output (which increases by more than income) increases by more than demand (which increases by less than income); (b) the excess demand for B (demand for imports) increases, because output decreases whilst demand increases. Therefore—leaving aside the small country case—on the world market at unchanged prices there will be an increase in both the supply of A and the demand for B and so—since the initial situation was of equilibrium—an excess supply of A and an excess demand for B. This will cause a decrease in p_A and an increase in p_B, so that p_B/p_A will increase, confirming the closed-economy results. As B is the importable, the terms of trade have moved against the country.

13.5 Technical Progress and International Trade

13.5.1 Types of Technical Progress

Before coming to grips with the analysis of the effects of technical progress on international trade, it is necessary to introduce the notions of neutrality and bias of technical progress. It should be remembered that we are considering solely

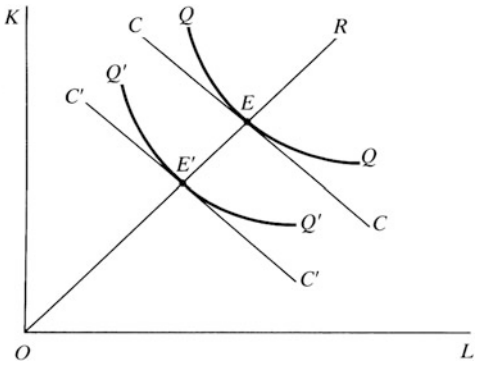

Fig. 13.6 Neutral technical progress

disembodied exogenous technical progress. For a general treatment of technical progress see, for example, Allen (1967, chap. 13) and Burmeister and Dobell (1970, chap. 3).

Among the various possible definitions, we shall adopt the traditional Hicksian definition (Hicks, 1932, 2nd ed.: 1963), according to which technical progress is neutral if, at unchanged capital/labour ratio, it causes an equiproportional increase in the marginal productivities of both factors, whilst it has a factor-saving bias if it increases the marginal productivity of the other factor more than proportionally to the increase in the marginal productivity of the saved factor. Instead of the factor-saving bias one can define a factor-using bias: technical progress has a factor-using bias if it increases the marginal productivity of a factor (the used factor) more than proportionally to the increase in the marginal productivity of the other factor.

It is then clear that capital-using is synonymous with labour-saving, and labour-using with capital-saving.

An equivalent definition is that—at unchanged factor-price ratio—neutral technical progress leaves the optimum factor ratio unaltered, whilst a factor-saving progress reduces the optimum ratio between this factor and the other. In other words a labour-saving technical progress reduces the optimum labour/capital ratio (that is, relatively less labour is used), and a capital-saving progress reduces the optimum capital/labour ratio, always at unchanged factor-price ratio.

In Fig. 13.6, QQ is the typical isoquant before technical progress; given the factor-price ratio represented by the slope of the isocost CC, the optimum input combination is found at E, where the factor-price ratio equals the marginal rate of technical substitution, which in turn is equal to the ratio between the marginal productivities. After technical progress, the isoquant shifts to $Q'Q'$ and, given the isocost $C'C'$ parallel to CC (the same factor-price ratio), the new equilibrium point is found at E', which lies on the same ray OR as E. Therefore K/L is the same at E' as at E.

Let us now consider the case of labour-saving technical progress. In Fig. 13.7, QQ and $Q'Q'$ are the isoquants before and after technical progress. Since the marginal productivity of capital has increased by a greater proportion than the

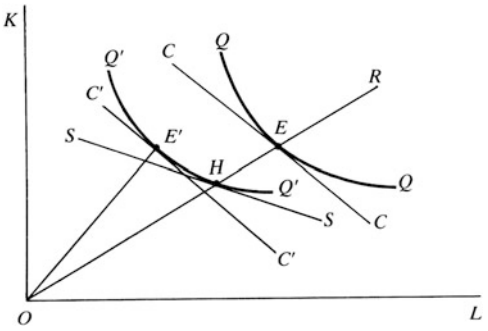

Fig. 13.7 Labour-saving technical progress

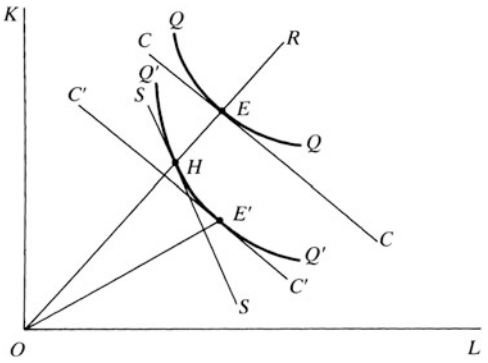

Fig. 13.8 Capital-saving technical progress

marginal productivity of labour, at the point of isoquant $Q'Q'$ where the K/L ratio is the same (point H), the MRTS (equal to MPL/MPK) is lower, as can be seen from the fact that SS is less sloped than CC. The new optimum input combination at unchanged factor-price ratio will be found to the left of H, for example at E', where the optimum K/L is higher and so L/K is lower.

Similarly, it can be checked (see Fig. 13.8) that in the case in which MPL has increased more than proportionally to the increases in MPK (capital-saving technical progress), the optimum K/L is lower at E' than at E.

13.5.2 Effects of Neutral Technical Progress on Production Levels and the Terms of Trade

The first result to be demonstrated is that neutral technical progress in a sector brings about—at an unchanged relative price of goods—an increase in the output of that sector and a decrease in the output of the other sector. For this purpose, as suggested by Findlay and Grubert (1959), we can use the Lerner-Pearce diagram (see Fig. 4.3). In Fig. 13.9 the isoquants of A and B are denoted by AA and BB, and the productive levels they represent correspond to the given commodity-price ratio (for details see

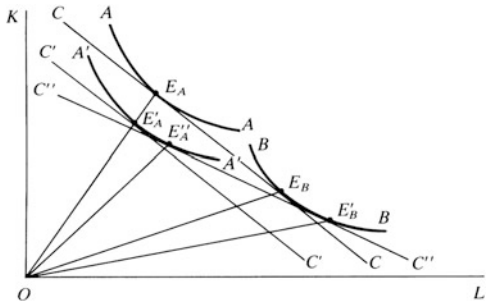

Fig. 13.9 Effects of neutral technical progress on factor intensities and price ratio

Fig. 4.3); the respective optimum input combinations are E_A and E_B. Let us assume that sector A enjoys a neutral technical progress: the AA isoquant shifts to $A'A'$ and, at unchanged factor-price ratio, the new optimum point is E'_A. However this is not a situation compatible with an unchanged commodity price ratio: in fact, at unchanged factor-price ratio, the same quantity of A (isoquant $A'A'$ represents the same output as isoquant AA, thanks to technical progress) now has a lower production cost (isocost $C'C'$ is below isocost CC), while the cost of producing the same quantity of B is unchanged; therefore, the exchange ratio (relative price) of the two commodities cannot remain unchanged.

For the commodity-price ratio to remain unchanged the factor-price ratio must change so that the cost of producing the quantity of B represented by isoquant BB and the cost of producing the quantity of A represented by isoquant $A'A'$ (which is the same as that represented by the old isoquant AA) are equalized. Graphically this amounts to finding a new isocost ($C''C''$) simultaneously tangent to $A'A'$ (at E''_A) and BB (at E'_B). The reader will note that capital intensity has decreased in both sectors and that the p_L/p_K ratio is lower (p_K/p_L is higher).

To sum up: given neutral technical progress in a sector, at unchanged relative price of commodities, the intensity of the factor used relatively intensively in that sector decreases in both sectors, and the relative price of this factor increases.

Let us examine the effects of neutral technical progress on the productive levels. For this purpose the box diagram is useful. In Fig. 13.10, let P be the initial point on the efficiency locus. The capital/labour ratio in sector A is clearly higher than in sector B and corresponds to the slope of OE_A and of OE_B, respectively, in Fig. 13.9.

Let us now inquire whether point P lies on the new efficiency locus which comes about as a consequence of technical progress. The answer is affirmative, since with first-degree homogeneous production functions, a neutral technical progress is equivalent to a mere renumbering of the isoquants: in other words, in Fig. 13.6, isoquant $Q'Q'$ occupies exactly the same place occupied by a lower-index isoquant before technical progress.

The system, however, cannot remain at P after technical progress has taken place. We have in fact seen above that, at an unchanged relative price of commodities, a neutral technical progress in sector A (the capital intensive commodity)

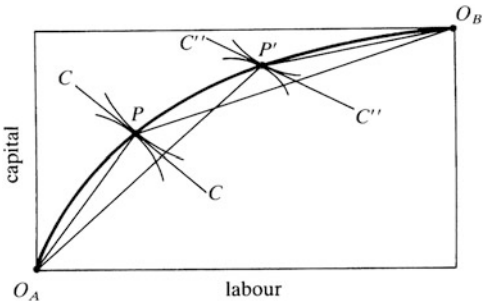

Fig. 13.10 Effects of neutral technical progress on outputs

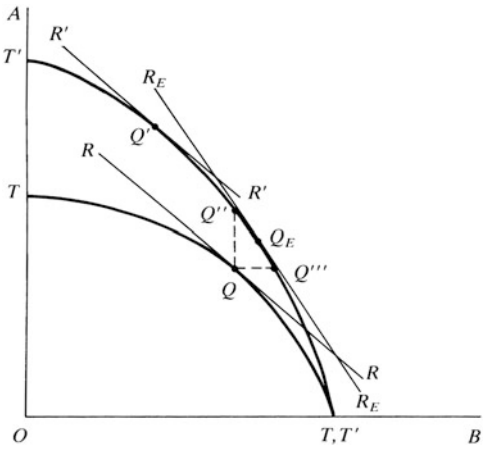

Fig. 13.11 Neutral technical progress and relative price of goods

causes a decrease in the capital intensity in both sectors. Therefore, the new equilibrium point will have to be somewhere to the right of P: in fact, the capital intensity will be lower in both sectors only at points on the PO_B stretch of the efficiency locus. Let P' be the new equilibrium point, where both sectors have a lower K/L ratio, corresponding to the slope of OE''_A and OE'_B respectively (Fig. 13.9). We observe that, at an unchanged commodity-price ratio, the output of commodity B is lower whilst that of A is higher.

We have thus proved the result stated at the beginning, that neutral technical progress leads to an increase in the output of the sector enjoying this progress and a decrease in the other sector's output, at unchanged relative price of commodities.

Point P', however, cannot be a point of general equilibrium if we bring demand into the picture. Technical progress brings about an increase in national income at constant prices: see Fig. 13.11, where the isoincome $R'R'$ represents a higher national income at constant prices than RR. Hence, if we exclude inferior goods, the demand for both commodities will increase. Now, since at an unchanged commodity-price ratio the output of B has decreased, there will be an excess demand for this commodity which will cause an increase in its relative price (and so a decrease in the relative price of A).

To sum up, neutral technical progress in a sector brings about a decrease in the relative price of the commodity produced by this sector.

This result can also be illustrated graphically by using transformation curves (as we did in the case of an increase in the endowment of a factor). In Fig. 13.11, TT is the initial transformation curve and $T'T'$ that which occurs as a consequence of neutral technical progress in sector A. Note that, as no technical progress has occurred in sector B, the intercept with the B axis of the new transformation curve is the same as that of the old one, because when all factors are employed in the B sector (where technology is the same) the maximum output of B remains the same.

At an unchanged commodity-price ratio (the line $R'R'$ is parallel to RR) the economy shifts from the equilibrium (production) point Q to Q', where the output of A is higher and that of B lower. As, assumedly, no commodity is inferior, point Q' (which corresponds to P' in Fig. 13.10) cannot be a general equilibrium point. The final equilibrium point will lie somewhere in the portion $Q''Q'''$ of the $T'T'$ transformation curve, where the outputs of both A and B are higher. At any such point—for example Q_E—the relative price p_B/p_A is higher (and so p_A/p_B is lower) than at Q'.

All this concerns the closed economy. As regards the open economy, we can follow exactly the same line of reasoning as in Sect. 13.4 with reference to Rybczynski's theorem. In fact, once we know that—at unchanged relative price of commodities—neutral technical progress in sector A brings about an increase in the output of A and a decrease in the output of B, and having assumed away inferior goods, we can proceed exactly in the same way as in Sect. 13.4 and show that the terms of trade p_B/p_A increase in any case, so that the situation will be better or worse according to whether A is the exportable or the importable.

This parallelism will be intuitive if one thinks that, as regards the effects on international trade, what matters is the increase in the domestic output of B and the decrease in the domestic output of A at unchanged relative price of commodities, as the causes of these changes in output (increase in the quantity of the factor used intensively in sector A or neutral technical progress in this sector) are irrelevant.

13.5.3 Effects of Biased Technical Progress

The effects of biased technical progress are more complicated, and we must distinguish the factor-saving technical progress occurring in the sector which is more intensive in the saved factor from that occurring in the sector which is more intensive in the other factor (the used factor).

13.5.3.1 Capital-Saving Progress in the Capital-Intensive Sector

As regards the former, we examine the case of capital-saving progress in the sector intensive in capital (the case of labour-saving progress in the labour-intensive

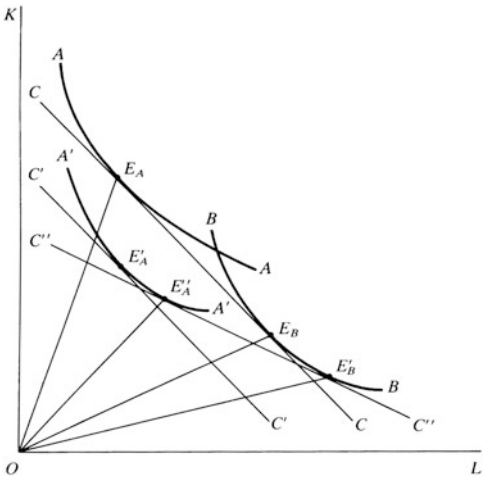

Fig. 13.12 Effects on factor intensities and price ratio of capital-saving technical progress in the capital-intensive sector

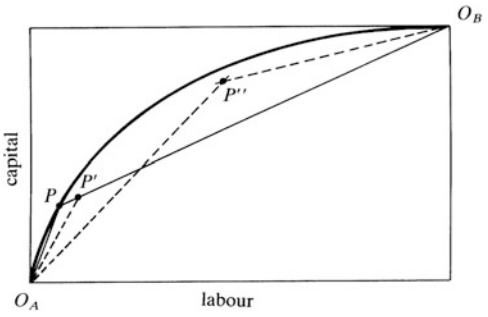

Fig. 13.13 Effects on productive levels of capital-saving progress in the capital-intensive sector

sector is perfectly symmetrical). In Fig. 13.12, which has the same structure as Fig. 13.9, capital-saving technical progress occurs in sector A (the capital-intensive commodity): the AA isoquant shifts to $A'A'$, as described in Fig. 13.8 and, at unchanged factor-price ratio, the new optimum point is E'_A. But, as the commodity-price ratio is assumedly unchanged, this point is not acceptable, as the same quantity of A now has a lower production cost whilst the production cost of B is unchanged; thus the exchange ratio (relative price) of the two commodities could not remain unchanged. It is then necessary for the factor-price ratio to change, so as to determine a new isocost ($C''C''$), tangent to both $A'A'$ (at E''_A) and BB (at E'_B): only in this way, in fact, will the production cost of the quantity of B represented by isoquant BB be the same as that of the quantity of A represented by isoquant $A'A'$ (which has the same index as isoquant AA).

It can be readily seen from the diagram that the capital intensity has decreased in both sectors, and that the p_L/p_K ratio is lower (p_K/p_L is higher). These effects are qualitatively similar to those found in the case of neutral technical progress in sector A (Fig. 13.9), and the effects on productive levels are also similar. In Fig. 13.13 P is the initial equilibrium point on the efficiency locus, with K/L ratios corresponding to the slopes of OE_A and OE_B in Fig. 13.12.

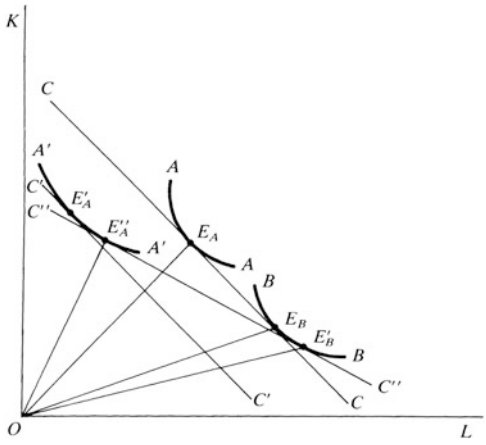

Fig. 13.14 Effects on factor intensities and price ratio of labour-saving technical progress in the capital-intensive sector: first case

As technical progress is biased, the new efficiency locus will not coincide with the old one, but it is possible to arrive at the results we are interested in without drawing it all. Let us begin by observing that point P'—at the intersection of the old ray O_{BP} (this has the same slope as OE_B in Fig. 13.12) and the ray O'_{AP} (this has the same slope as OE'_A in Fig. 13.12)—belongs to the new efficiency locus. In fact, point E'_A in Fig. 13.12 has been determined at unchanged relative factor prices, so that E'_A the isoquant $A'A'$ has the same slope as isoquant AA has at E_A. Now, given the property of radiality of first-degree homogeneous production functions (see Sect. 19.1), along ray O_{BP} the isoquants of B maintain the same slope, so that at P' the slopes of the isoquants of A and B (not shown in the diagram) are the same as the respective slopes at P and thus are equal (the A and B isoquants are tangent at P'): it follows that P' is an efficient point belonging to the new locus. It goes without saying that, as P' is nearer than P to the origin O_B, it represents a lower amount of B and, of course, a higher amount of A.

But, as we have shown above, point P' cannot be accepted if the relative price of commodities has to remain unchanged: from Fig. 13.12 we see that the capital/labour ratio further decreases in sector A, and decreases in sector B as well. Thus we shall get to a point P'' on the new efficiency locus (this is not drawn in the diagram for simplicity) such that: slope of O''_{AP} = slope of OE''_A in Fig. 13.12, and slope of O''_{BP} = slope of OE'_B in Fig. 13.12. As point P'' is still nearer to the origin O_B, we have proved that the output of B decreases whilst that of A increases. From this point onwards the analysis of the effects on international trade and on the terms of trade is identical with that explained with regard to neutral technical progress.

13.5.3.2 Labour-Saving Progress in the Capital-Intensive Sector

We must now examine the effects of labour-saving technical progress in the capital-intensive sector (the case of capital-saving progress in the labour-intensive sector is

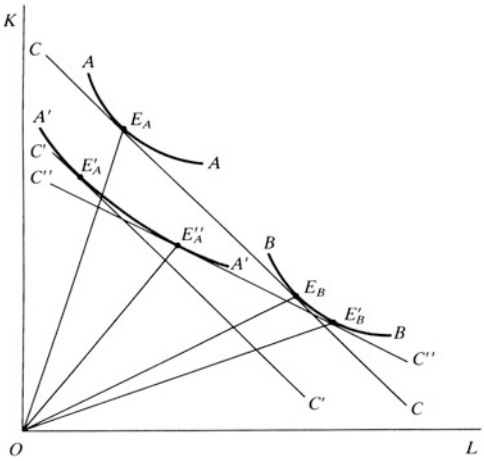

Fig. 13.15 Effects on factor intensities and price ratio of labour-saving technical progress in the capital-intensive sector: second case

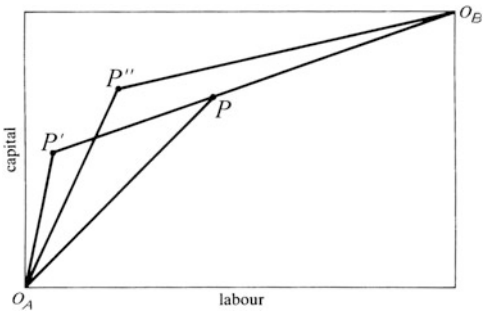

Fig. 13.16 Possible effect on productive levels of labour-saving technical progress in the capital-intensive sector

perfectly symmetrical). In Fig. 13.14, labour-saving technical progress occurs in the capital-intensive sector A. With the usual procedure, by now familiar to the reader, it can be seen that for the relative price of commodities to remain unchanged the isocost must shift to $C''C''$, whence a decrease in p_L/p_K. The capital intensity certainly decreases in sector B whilst the outcome in sector A is ambiguous. In Fig. 13.14 we have shown the case in which K/L increases in sector A; the opposite case in shown in Fig. 13.15 (the borderline case in which K/L remains unchanged in sector A is also possible, but unlikely). In any case K/L decreases in sector B. Thus the effect on productive levels is ambiguous. In fact, in the case in which the K/L ratio decreases in both sectors, the result will be the same as in the cases analysed above (the output of B decreases and that of A increases), whilst in the case in which K/L decreases in sector B but increases in sector A, it is possible (though not necessary) for the output of B to increase and that of A to decrease.

This possibility is represented in Fig. 13.16, where for simplicity's sake we have drawn only the equilibrium points: the initial one (P); the one corresponding to E'_A in Fig. 13.14 (i.e. P'), which is found at the intersection of ray $O_B P$ with the ray having the same slope as OE'_A and is a point of the new efficiency locus; the one corresponding to the slopes of OE''_A and OE'_B in Fig. 13.14, i.e. P''. The equilibrium

point P'' is farther than P from origin O_B (so that the output of B is higher) and nearer to origin O_A This is not sufficient for the output of A to be lower as we have to account for technical progress; it is however possible that the initial A isoquant through P shifts downwards by an amount insufficient to bring it below P'', so that we shall find that the isoquant through P'' has a lower index than that of the initial isoquant through P.

We must then conclude that in the case of a labour-saving progress in the capital-intensive sector, the outputs can move in any direction. As a consequence, the direction in which the terms of trade will move is indeterminate.

13.5.4 Conclusion

It may be useful to sum up the results concerning the effects of technical progress on the terms of trade.

1. Neutral technical progress in a sector causes a decrease in the relative price of that sector's product. The movement of the terms of trade will therefore be favourable (unfavourable) to the country if the sector concerned produces an importable (exportable).
2. Capital-saving technical progress in the capital-intensive sector and labour-saving technical progress in the labour-intensive sector have unambiguous effects, qualitatively similar to those of case (1): the relative price of the commodity produced in the innovating sector decreases. The terms of trade will therefore shift in favour of (against) the country if the innovating sector produces an importable (exportable).
3. Capital-saving technical progress in the labour-intensive sector and labour-saving technical progress in the capital-intensive sector have indeterminate effects, as the relative price of the commodity produced in the innovating sector may either increase or decrease. Note, finally, that once we know the effects of technical progress on the terms of trade we can determine the effects on the country's welfare: if the terms of trade improve, social welfare will certainly improve, whilst if they move against the country, there is the possibility of immiserizing growth (see Sect. 13.3.2).

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