RAW MATERIALS IN INTERNATIONAL TRADE[1]

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Discussion about the relative movements of raw materials and manufactured goods in international trade has generally proceeded along two different lines. One approach, essentially short run and cyclical, has focused on the relatively larger fluctuations in demand for raw materials and the concomitant wider variations in exports and prices. The other approach, concerned more with long run factors, has maintained that the process of economic growth inherently leads to a diminished role for raw materials in relation to manufactured goods. According to this view, demand for raw materials should be decreasing relative to the demand for industrial products. This article will consider some of the implications of this latter approach.

While discussion of this question can be traced back to the inter-war period, only in the 1950's has it attained prominence in the economic literature. During this decade, the subject has been frequently treated in the annual reports of international organizations and has appeared occasionally in economic journals.[2] Since two comparatively recent sources

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[1] This article is a revised version of a memorandum prepared for the Swedish Long Term Planning Committee (1959 års Långtidsutredning). I also want to express my gratitude to Messrs.Ö. Johansson and A. Lindbeck, for valuable and constructive criticism.

[2] GATT, International Trade 1955 (Geneva, 1956), Trends in International Trade, A Report by a Panel of Experts (Geneva, Oct. 1958), hereinafter cited as GATT-Report;

UN, World Economic Survey 1955 (New York, 1956), World Economic Survey 1958 (New York, 1959), Commodity Survey 1957 (New York, 1958), Commodity Survey 1958 (New York, 1959);

ECE, Economic Survey of Europe in 1957 (Geneva, 1958).

W. A. Lewis, World Production, Prices and Trade, 1870–1960, in the Manchester School of Economic and Social Studies 1952, p. 105.

A. K. Cairncross and J. Faaland, Long Term Trends in Europe's Trade in the Economic Journal 1952, p. 25.

R. Nurkse, Patterns of Trade and Development, Wicksell Lectures 1959 (Stockholm, 1959).

provide exhaustive studies of this area and earlier works add only minor details, we will refer, in the main, only to these two sources.[1]

The point of departure for the analytical portion of almost all of these studies has been a description of the shape taken by the historical development. Comparisons have generally been made between trade and production of raw materials, and between trade and production of manufactured goods in the latter part of the 1920's and the middle of the 1950's. An attempt has then been made to "explain" the observed changes between these dates in terms of factors contributed by economic growth. Finally, there has been a concluding discussion of the significance of these movements for future trade between the primary producing and industrialized countries.

This format will be retained in the following study. Part A will include a brief description of reported empirical developments, while a brief account of the offered explanations is given in Part B. Part C will be devoted to an examination of the stated propositions with the use of a simple model. A formal treatment of the more important aspects of this model will be provided in a concluding appendix.

A. The empirical development

Some information concerning the development of world trade since 1928 is contained in Table 1 below.

Table 1.

	Exports from					
	Non-industrialized countries		Industrialized countries		Total	
Year	Value[a]	Volume[b]	Value[a]	Volume[b]	Value[a]	Volume[b]
1928	10.4	100	21.4	100	31.7	100
1955	28.2	138	53.4	139	81.7	139
1957	30.9	151	66.7	162	97.5	158

[a] Value in thousand millions of dollars. [b] Index 1928 = 100.
Source: GATT report p. 20.

[1] GATT Report; Nurkse, op. cit.

Although the non-industrialized countries are almost exclusively exporters of raw materials and the industrialized countries exporters of manufactured goods, a few countries in the latter group, e.g. Sweden, have significant raw material exports.

During the period studied, 1928–1957, total world trade tripled in value but registered only a 50% increase in volume. Both trends were displayed by the industrialized as well as the primary producing countries. From the material in Table 1, it is difficult to note any tendency for raw material exports to lag behind manufactured goods, particularly since the terms of trade between industrialized and non-industrialized countries have remained substantially unchanged. On the other hand, a lag in the growth of total world trade behind the growth in total production can be shown: production increased by more than 100%, which was more than twice the increase in the volume of world trade.

In order to demonstrate the diminished importance of raw materials in world trade, the above data must be somewhat revised. If we exclude petroleum, because of its special position,[1] the remaining raw materials can be distributed into the following categories.

Table 2. Changes in volume and prices of exports of raw materials from non-industrialized countries, distributed in various commodity groups (excluding petroleum).[a] Index 1928 = 100.

	Non-tropical foodstuffs		Agricultural commodities		Tropical foodstuffs		Minerals		Total	
Year	Volume	Price	Volume	Price	Volume	Price	Volume	Price	Volume	Price
1928	100	100	100	100	100	100	100	100	100	100
1955	86	177	140	174	135	253	144	223	119	194

[a] Calculations are based on a sample of exports from non-industrialized countries. This sample has almost exactly the same development as all non-industrialized countries taken together for both volume and value of exports.

Thus, by excluding petroleum—the export volume of which increased by a factor of six between 1928 and 1955—the relative decline in the growth of raw material exports becomes evident. All other primary products increased by less than 20%, while during the same period exports

[1] GATT Report, p. 22; Nurkse op. cit.

from the industrialized countries increased in volume by almost twice that precentage, according to Table 1. The least favorable movement was that of non-tropical foodstuffs which dropped almost 15% in volume. The export volume for the other raw material groups, however, increased at approximately the same rate as the increase in manufactured goods and hence in the case of these groups a relative decline in the importance of raw materials can not be shown. It is rather surprising that the GATT Report omits mention of these observations.

We may further group the non-industrialized countries according to their most important export. In Table 3 below, the value of exports in 1955 for these countries is given.

Table 3.

Countries exporting	Index 1955 (1928 = 100)
Non-tropical foodstuffs	182
Agricultural commodities	203
Tropical foodstuffs	359
Minerals	370
Petroleum	1175

Source: GATT report, p. 23.

Comparing these figures to a corresponding index of 250 for the exports of industrialized countries (cf. Table 1), we find that of all the primary producing countries, only those producing non-tropical foodstuffs and agricultural commodities have lagged behind the average growth in exports for industrialized countries. Again, no comment on this is found in the GATT Report.

Moreover, several so called "semi-industrialized" countries have been classified among the non-industrialized countries, whose income from exports appears to have undergone a less favorable development than that of all the primary producing countries. The income of the semi-industrialized countries from exports doubled between 1928–1955, whereas the income of the latter group tripled.[1]

These are, in brief, the major aspects of the development which has provided the foundation for analytical treatment. Nurkse as well as the GATT-report found it possible to conclude from the statistics that a

[1] GATT Report, p. 24. This point is elaborated upon in Part C.

lag in the growth of raw material exports had occurred. This relative stagnation can be shown most clearly in the comparison beween the increase in trade of total raw materials and the increase in total world production. On the other hand, as has been shown above, the decline in the share of raw materials in world trade has hardly been noticeable. Indeed, this relationship has proved to have been of minimum importance in later discussion of raw material movements. It is therefore surprising, in view of such doubtful proof of stagnation in this area, to note that, at least at the outset, this decline has been considered as so significant and disturbing.[1] Since at a later stage in the cited studies the question of the declining share of raw materials in world trade has been dropped from discussion, it will not be subjected to further examination here.

B. Some explanations offered for the observed trends.

The factors deciding the historical development have been grouped according to their origin from the supply or the demand side.[2]

Factors from the demand side

1. The income elasticity for many agricultural commodities tends to be less than one. Increases in income have therefore tended to lead to a decreased demand for these products relative to manufactured goods.
2. Structural changes in the process of economic growth. Industrial sectors with a relatively high demand for raw materials have been declining in relation to sectors with low material needs, e.g. the shift from "light" industry to "heavy" industry.
3. Technological changes. The invention of synthetic substitutes for raw materials; innovations in production methods which have induced economies in raw materials, e.g. metal reprocessing.
4. New products have contained relatively little raw material content, e.g. television sets.
5. Protectionism in industrial countries, particularly that which has affected agricultural commodities.

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[1] Cf. e.g. Nurkse p. 22, where the "top heavy structure" of world trade is discussed.
[2] GATT Report, pp. 42–43; Nurkse pp. 23–27.

Factors from the supply side

6. Exhaustion of resources: soil erosion and mine depletion in primary producing countries.

7. Movements in relative costs which have been unfavourable to the primary producing countries.

It has been suggested, however, that the factors on the supply side, i.e. 6 and 7, have been relatively unimportant and that development have been determined primarily by demand from the industrial countries.[1] As support for this hypothesis certain studies have been cited which show that the relation between total input of raw materials and total output of manufactured goods has markedly decreased since the immediate pre-war period.[2]

The reasoning has been that while a given increase in real income in the industrial countries would clearly lead to an absolute increase in the demand for raw materials, this increase would always be relatively less than the increase in demand for manufactured goods. The downward trend in the relation between the world raw material exports and total world production has thus been attributed almost entirely to the relative decline in the growth of demand.

This conclusion has then been used as a starting point for a consideration of the problem of the optimum allocation of additional resources —in the form of labour as well as capital—between industrial and raw material production. In view of the stagnation in demand for raw materials, it has been assumed that an increase in supply would not be absorbed by the relatively declining demand. This situation has been described in a slightly different manner, "that while a contry's established comparative advantage in the current export products may be high indeed, its *incremental* comparative advantage in these lines may be zero or actually negative".[3] The economic policy implications of the discussed trends therefore have been that the developing countries should not concentrate any further on raw material production despite their current comparative advantage.

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[1] Nurkse, p. 26; Galt Report. pp. 42–43, 51.

[2] GATT, International Trade 1955 (Geneva, 1956) p. 12. According to these calculations the relation between input of natural raw materials and output of manufactured goods dropped from 25.0 in 1938 to 17.6 in 1955.

[3] Nurkse, p. 57

We have already seen that the empirical evidence is not fully convincing in its support for the interpretation that there has been a heavily disparate development in raw material and industrial exports. Moreover, in both cited works, the analytical discussion has been quite brief. The models which underlie the conclusions have received no formal presentation and can at best only be inferred from the list of development-determining factors. To the extent that some of these factors have already been subjected to rigorous analysis by another source, this brevity is quite justified. This is true, for example, for the case of low income elasticity which has been intensively analyzed by J. R. Hicks and H. G. Johnson.[1]

However, for those raw materials having a demand which is derived indirectly from the demand for manufactured goods one cannot rely solely on income elasticity analysis, an approach which is more appropriately addressed to final demand. In the next section we will therefore present a simple supply and demand model which may be more suited to an analysis of the case of "derived demand". The model will be given in diagram form and based upon relatively elementary economic principles. In a special appendix, it will receive a more rigorous treatment.

C. A simple model for analysis of development

As already suggested, discussion in the articles referred to has focused on the relationship between quantities of raw materials and manufactured goods. The following model will attempt to demonstrate how this relation can reach equilibrium, and, moreover, how equilibrium once achieved may be influenced by economic growth. If we consider the problem in aggregate terms, we have in principle only two products, raw materials (R) and manufactured goods (I). In industrial production, raw materials along with other factors are used as inputs while raw materials are produced only with the help of these latter factors.[2] Pro-

[1] J. R. Hicks, An Inaugural Lecture, Oxford Economic Papers, June 1953, p. 130; H. G. Johnson International Trade and Economic Expansion, Manchester School of Social and Economic Studies 1955, p. 65.

[2] This approach does not differ in principal from the case where raw materials are considered also as input in the R-sector. In that case gross production is a function both of the use of raw materials and the use of other factors. From profit maximizing conditions we know, however, that the marginal productivity of raw materials must always equal one, since the price relation between output and input always equals one

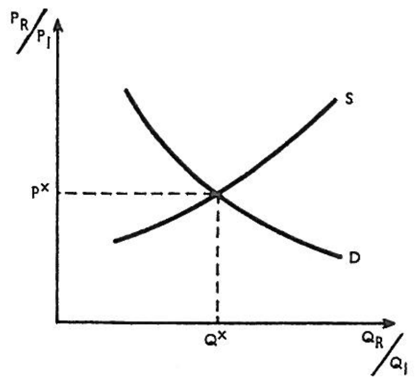

Fig. 1.

duction and supply of raw materials are therefore always equal. Under these assumptions, the market demand for raw materials will come only from the industrial sector.

In the diagram above the price relation between the two products, P_R/P_I has been presented on the vertical axis and the relation between the corresponding quantities Q_R/Q_I on the horizontal axis. The intention is to construct demand and supply curves which show how the relation between demanded and supplied quantities changes according to changes in the price relation.

The demand curve (D in the diagram) has been given the "classical" negative slope so that a relative increase in prices causes a decrease in the demand for raw materials per unit of manufactured products. The negative slope is decided by two different factors. Firstly, as P_R/P_I increases a substitution of other factors of production for raw materials will occur. At any given volume of production of manufactured goods, therefore, the demand for raw materials will be lower. Since the possibilities for substitution, at least in the short run, might be relatively limited, the negative slope of the curve will be fairly slight. But this negative slope is accentuated by the fact that the pattern of industrial production undergoes a change as a result of relative increases in the price of raw materials. The prices of manufactured products with a high raw material content will tend to increase relative to those products with a lower raw

in this case. We can therefore solve raw material consumption as a function of other inputs from this condition and then substitute the result in the production function. After that, net total production (exclusive of internal use of raw materials) can be written as a function of the remaining factors of production.

material content, which in turn would lead to a reallocation of final demand in a manner unfavorable to raw materials. There is, therefore, a certain amount of justification for the assumption that demand—at least in the not too short run—displays a certain degree of price sensitivity.

This demand curve is valid only under assumpions of a given level of technical knowledge, a related level of real income, and full utilization of existing resources. The question arises, therefore, of how the process of economic growth will alter the shape and position of the curve? Here we must separate two different types of inducement to change: firstly, those which arise when technological innovation causes changes in the production functions and secondly, those which result when the composition of final demand changes as a consequence of increases in real income.

The latter type clearly coincides with the explanations mentioned, under points 2 and 4 above, for the relative decline in demand for raw materials. The question is, of course, whether this tendency is general and supersedes opposing forces, and whether the demand development as a whole has actually been characterized by this type of structural change. The cited examples, however, appear to be rather "striking" and since convincing opposing argument has not been introduced, there is reason to suppose that the process of economic growth could contain a "raw material-saving bias". Changes in the composition of ultimate demand would therefore tend to shift the demand curve to the left, i.e. from D_1 to D_2 in diagram 2 below.

In the appendix, the effects of technological change on derived demand are studied under the assumption of a "neutral" technological development.[1] Not even in this simpler case is it possible to establish any single-valued relationship between growth and the shift of the D-curve on a priori grounds. The question of whether the shift shall be positive or negative for Q_R/Q_I is determined by the well-known elasticity of substitution.[2] Without knowing whether this elasticity numerically exceeds, or is exceeded by, one, it is not possible to say whether the effect of a "neutral"

[1] A "neutral" technological development does not influence the marginal rates of substitution between raw materials and other resources. In effect, this follows the definition of neutrality used in theories of production and distribution, see e. g. Hicks, The Theory of Wages.

[2] See Hicks, The Theory of Wages.

technological development is to shift the demand curve to the left or the right in the diagram.

A "non-neutral" technological development would naturally further complicate the picture, as it would influence the position of the demand curve, quite independently of the elasticity of substitution. Under point 3 on the list of development-determining factors mentioned above, the authors have argued that technological development has this "non-neutral" character, and that the dominant tendency has been one of raw material saving. As is well known, however, it is difficult to classify a path of technological development as "biased" in one or another direction. One must be extremely careful in reaching such a conclusion, particularly in the absence of a close analysis of the effects of technological development on the production function.[1]

The cumulative effects of the growth process on the position of the demand curve is thus the net result of a rather complicated interplay among technological development, factor substitution and the changed composition of final demand. Only in connection with the last mentioned factor, can one conclude that the relative demand for raw materials has probably been declining. The likely effects of the two preceding factors, in the absence of significant empirical findings, remain open to speculation and hence leave unresolved the problem of total effects of economic growth.

The connection between the price relation and the relation between the quantities supplied—which can be ascertained without resort to extensive analysis—is a question of optium allocation of given resources. The higher the relative price of raw materials, the greater will be the amount of resources utilized in raw material production and the supply curve (S in the diagram) should therefore—in the not too short run—have a positive slope. In the appendix where the positive slope is demonstrated with the use of a simple allocation model, the elasticity of supply with respect to the relative price appears as a result of the fact that already utilized natural resources are worked more intensively with the help of

[1] A "non-neutral" development would mean one which effects the marginal rates of substitution. Since we are dealing with aggregate production functions, it is clearly difficult, perhaps impossible, to discover a common characteristic of the effects of technological growth from the starting point of some observed innovations in production methods.

other factors of production, i.e. capital and labor, or that resources of successively lower quality must be taken into production.

As the supply curve only reflects the optimum allocation of mobile resources it is exposed to changes induced by increases in resources and technological development. We therefore see at once that the supply curve, as well as the demand curve, is dependent on the process of economic growth.

Also, at a given allocation of resources, differences in the force of technological development can cause, a shift in the position of the supply curve. If development proceeds at a faster rate in the I sector than in the *R* sector, the increase in the supply of manufactured goods will be relatively greater. In that event, the *S* curve would shift to the left in the diagram. These tendencies are reinforced by the influence of technological development on the allocation optimum. Since technological development by assumption, increases productivity relatively faster in industrial production than in raw material production, some of the mobile resources will shift from the *R* sector to the *I* sector. This redistribution will reinforce the shift of the curve to the left in the diagram.

It thus appears that the change in the position of the *S*-curve resulting from technological development is related to the disparity in the increase in productivity within both sectors. One part of this relationship can be simply stated; as long as technological development results in a greater rise in productivity in industrial production than in raw material production, the *S*-curve throughout its entire length will shift to the left. If, however, a relatively greater increase in productivity occurs in the raw material sector, the shift will not be uniform. In this situation the "new" *S*-curve is reached by simply turning the "old" around one point. On pure a priori grounds we can at most say that the greater the increase in productivity within the *R*-sector in relation to the *I*-sector, the greater will be the portion of the new supply curve whose is to the right of the old curve in the diagram.[1]

Moreover, the effects of an increase in the available capital and labor resources will not necessarily be uniform. In a situation where natural resources remain unexploited, not because of their low return but rather

[1] Cf. Appendix, where the effects of a "neutral" technological development on the *S* curve are formally treated.

because of a shortage of other factors of production—primarily capital—an increase in that factor will result in an increase in the supply of raw materials. If, on the other hand, raw material production can be increased only through more intensive exploitation of already utilized resources—an assumption made in the appendix—an increase in other factors will lead only to an increase in the supply of manufactured goods.

The total effects of economic growth on the movement of the supply curve are thus also undecided. Only a rather intricate analysis of empirical data can provide the information essential to more definite conclusions.

For a given point of time, an equilibrium in the price relation P^* and in the quantity relation Q^* exists in the intersection between the D and S curves. Only at this price relation, do supply and demand surpluses equal zero on both markets. For the intersection implies that the magnitude of the relation between the quantities demanded is equal to the magnitude of the relation between the quantities supplied; relative excess demand must be the same size, in both markets—even if they do not equal zero. If we further assume that Say's law applies, these excesses of demand must be numerically equal and opposite in sign. The only situation which fulfils these two conditions occurs when both excess demands equal ± 0.

The equilibrium solution is obviously exposed to the entire complicated interplay of the various factors which follow from economic growth. Starting with curves S_1 and D_1 and equilibrium position E_1 in Fig. 2, let us suppose economic growth leaves the supply curve unaffected. The demand curve, however, is shifted to D_2 for reasons expounded above. The new equilibrium position, E_2 means, as is clear from the figure, a smaller relation Q_r/Q_I in comparison with E_1. This seems to be precisely the case envisaged by the authors of the GATT Report and Nurkse.

However, a reduction in the relation Q_R/Q_I may be achieved without any shift in the demand curve. If economic growth entails a relatively lesser productivity increase within the raw materials sector than within the industrial sector, and a "neutral" demand reaction, a new equilibrium will occur at the intersection of S_2 and D_1. That point, E_3, will have exactly the same value for the quantity relation as E_2. Purely on the basis of empirical calculations of input relations such as those relied

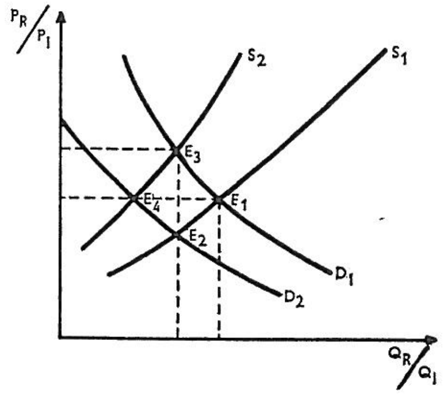

Fig. 2.

upon in the cited studies, one cannot, therefore, decide whether the changes occurred from the demand or the supply side.

Equilibrium positions E_2 and E_3 differ, however, in one respect. E_3 involves a more favorable price relation for raw materials. By studying the combined changes in the price and quantity relations, it is possible, at least in certain cases, to go further than an analysis based solely on changes in the quantity relation. We will treat in this way two cases which are relevant to the studies cited.

1. Between 1928 and 1955, according to these studies, the quantity relation dropped while the terms of trade between raw materials and manufactured goods remained substantially unchanged. Assuming that the supply curve is not infinitely elastic, such a development could only occur through shifts in supply and demand (from an original $S_1 - D_1$ situation) of the sort suggested by the combination $S_2 - D_2$ (i.e. equilibrium position E_4) in the diagram. In that event, the supply side must have taken an active role in the reduction of the quantity relation.

2. Between 1938 and 1955, the quantity relation similarly dropped but the terms of trade for raw materials significantly improved.[1] The movement from E_1 to E_3 in the diagram illustrates such a development. During this period, the development of the price and quantity relations remained consistent with a completely "neutral" demand development. However, the supply side could not have had a wholly neutral effect.

This analytical apparatus clearly offers an extremely simplified pic-

[1] See GATT Report, pp. 20, 41.

ture of the highly complicated reality.[1] However, even if the model is unrealistic it ought to demonstrate that, under the assumptions made, conclusions of the sort contained in the cited studies are not valid. By introducing the relative price development into the analysis, results are obtained which suggest that a relatively unfavorable productivity development in the raw material sector may have been equally responsible for the trend towards decreased raw material content in the total world output as the "raw material-saving" bias in a growth-induced increase in demand.

Along with these rather general views on the structure of the analysis, it may be worthwhile to indicate some of the more specific problems.

One of these is the complication introduced by the use of "synthetic" raw materials. As has been previously mentioned, the growing use of synthetic substitutes has been interpreted as purely a demand effect. Such a conclusion is valid, however, only to the extent that the natural raw materials are imperfect substitutes for the synthetics; i. e. to the extent that natural raw materials lack certain qualities, found in synthetics, which are essential to production. In areas where the two kinds of raw materials are perfect substitutes the above interpretation is not valid. For at each given price relation, consumption will occur in such a way that at the margin it becomes irrelevant from an economic point of view whether usage is increased for either of the two goods.

If, in such a situation, a considerably stronger increase in the use of synthetics is observed, the reasons must come from another source than the demand side: i.e., the active agent must have come from the supply side. A larger increase in productivity within the "synthetic raw material sector" has resulted, via the mechanism described above, in a change in the composition of supply at every price relation. This case can be demonstrated in the diagram in Fig. 2—if we let Q_R designate the quantity of natural raw materials—as a shift of the supply curve to the left.

Until now, our interest has been focused wholly on the factors determining the equilibrium position for the output coefficient. This approach

[1] The analytical technique is based on assumptions not explicitly mentioned above, e. g. complete mobility for the factors of production between both the raw materials and the industrial sector, perfect competition, production functions homogenous of degree one, etc. Cf. Appendix.

is justified because shifts in demand and supply curves can most simply be studied with the use of such a model. The cited studies, however, were concerned with the decline in *exports* from the raw material producing countries in relation to world *industrial production*. It is clear that this relation is influenced by the factors that have already been discussed but there are in addition several others which complicate the analysis.

Firstly, we have the obvious point that a large part of the demand for raw materials is supplied by production within the industrialized countries. In many cases, these products are perfect substitutes for the products of the primary producing countries. The analytical aspects of the problem closely resembles the treatment already given to the case of synthetic raw materials and hence will not be further pursued.

Another equally obvious factor which may also have limited increase of exports from the primary producing countries—without having anything to do with a weak demand development—is their productive capacity. The insignificant growth in the productive capacity of primary producers may be explained in several ways.

In certain cases it can be attributed to scarcity in the supply of other resources such as capital and skilled labour. In other cases, the increase in resources has been allocated to the production of industrial goods rather than raw materials. As has been mentioned, the group of countries classified as primary producers also includes "semi-industrialized" countries. The remarkably weak increase in raw material exports from these countries can be viewed as a reflection of the changed composition of optimum supply. The supply curve, in other words, has shifted entirely to the left in the diagram, as a consequence of increases in available resources and technological development.[1]

The question arises, therefore, whether these countries can be considered as examples of the proposition that the comparative advantage in raw material production for additional resources has been essentially reduced by the relative decline in demand. In our model, we can express the comparative advantage for raw material production by stating

[1] In order for the entire change in the production mix to be determined by the growth process, it is necessary that the price relation, P_R/P_I, remain unchanged. In the present case, however, we know only that this is true for all raw materials in relation to all manufactured goods, and not whether the same stability characterizes the price relation between the raw materials and manufactured goods of the semi-industrialized countries.

that at every given price relation, the country with the comparative advantage has a higher Q_R/Q_I for the optimum composition of supply. [If the supply curves S_1 and S_2 in Fig. 2 represent two different countries at a given point in time, country 1. may be said to have a comparative advantage in raw material production. The market supply curve will be somewhere between S_1 and S_2 and the equilibrium position will be at the intersection of this supply curve with the market demand curve.]

From the earlier discussion, it is obvious that shifts in the demand curve can occur without changes in the supply curve. We can therfore conclude directly that there is no necessary relation between the demand development and comparative advantage. This is, of course, a consequence of the fact that the demand function is decided by the production function in the industrial sector while the supply function—and thereby the comparative advantage—is determined by the production functions in *both* sectors.

As has been earlier mentioned, the model discussed in the Appendix results in the allocation of the additional productive resources to the industrial sector. This provides an example of the situation where although raw material production enjoys a comparative advantage with respect to *existing* resources, at the margin the comparative advantage lies with industrial production. This particular quality of the model is decided, however, by wholly different factors than a movement of the demand curve; we would obtain the same results whether the demand curve, as a result of the growth process, shifted upwards, downwards, or remained unmoved.

Concluding remarks

Although this discussion of the various studies of relative raw materials and manufactured good movements has been strongly critical, it should not be interpreted to mean that little or no significance should be ascribed to the demand side. It is self evident that a more favourable demand development would have led to a more favourable development in volume and prices for raw material exports. Moreover, there is no wish to criticize the basic notion—namely that economic growth might have imparted a raw material-saving bias to the development of demand.

The lack of a model as a framework for analysis was rather keenly felt, however, and there was an instinctive reaction to the attempt to explain too much with only the use of the observed decline in the growth of raw material *demand*. Certain aspects of the historical development appear to be rather difficult to explain against that limited background and an enlargement of the focus to include a combination of supply and demand analysis seems to be required. This is particularly true for the suggested relationship between the demand development and comparative advantage, which apparently leaves several loose ends. There is no reason to believe that the simple model that has been presented in this article can give a deeper insight into these problems; rather, it should be viewed as a starting point to a more intensive analysis. On the basis of the empirical findings above, it seems plausible that a lot could be gained by disaggregation of different products as well as of different types of countries.

APPENDIX

The *S*- and *D*-curves in the diagram can be formally derived in the following way: Let Q_I, Q_R, R_I, L_I, L_R and P represent respectively, supply of manufactured goods, supply of raw materials, use of raw materials in industrial production, employment[1] in industrial production, employment in raw material production and the price relation between raw materials and manufactured goods. The production function for the industrial sector is

$$Q_I = F_I(L_I, R_I) \cdot A_I(t), \tag{1}$$

where $A_I(t)$ is a productivity parameter. If we assume that (1) is homogeneous to the first degree we have

$$\frac{Q_I}{R_I} = A_I(t) \cdot f_I(r), \tag{2}$$

where $r = (L_I/R_I)$.

Applying the profit maximization condition we further obtain

$$\frac{\partial Q_I}{\partial R_I} = p. \tag{3}$$

The function (3) is homogeneous of degree 0 in L_I and R_I since (1) is homo-

[1] Labor stands as a symbol for both capital and labor.

geneous to the first degree. We can further assume that P is a monotonically increasing function of r (cf. (7) below). Inversion of (3) thus gives a single-valued function

$$r = \phi(P), \tag{4}$$

which is then substituted in (2)

$$\frac{R_I}{Q_I} = [A_I \cdot f_I\{\phi(P)\}]^{-1}. \tag{5}$$

This is obviously the D-curve in the diagram, i.e. the derived demand for raw materials per unit of manufactured goods produced. The slope of the D-curve,

$$\frac{dD}{dP} = -A_I^{-1} \cdot \{f_I(r)\}^{-2} \cdot \frac{df}{dr} \cdot \frac{d\phi}{dP}, \tag{6}$$

is now to be determined with respect to sign. From (3) and (4) it follows that

$$\frac{d\phi}{dP} = \left[R_I \cdot \frac{\partial^2 Q_I}{\partial R_I \partial L_I}\right]^{-1} > 0. \tag{7}$$

Since $A_I^{-1} \cdot \{f_I(r)\}^{-2} \cdot (df/dr)$ is also positive, the D-curve in the diagram must, according to (6), have a negative slope.

In order to find the supply curve (S) in the diagram, we have to determine the allocation of resources between the I- and R-sectors, as a function of P. For this a restriction for resources is required.

$$\bar{L}(t) = L_R + L_I, \tag{8}$$

and a production function for the raw materials sector

$$Q_R = A_R(t) \cdot F_R(L_R), \tag{9}$$

where Q_R designates net raw material production (i.e. excluding internal use of raw materials) and $A_R(t)$ is a productivity parameter.

From profit maximization conditions in both sectors we now obtain.

$$\frac{\dfrac{\partial Q_I}{\partial L_I}(L_I, R_I)}{\dfrac{dQ_R}{dL_R}\{\bar{L}(t) - L_I\}} = P, \tag{10}$$

where $\{\bar{L}(t) - L_I\}$ has been substituted for L_R according to (8).

Together with (4), (10) gives a system of two equations with variables L_I, R_I and P; $\bar{L}(t)$ is exogeneously determined. We can therefore solve L_I and R_I as functions of P, $L_I(P)$ and $R_I(P)$. If these functions are substituted in the expression for the proportion between Q_R and Q_I, viz.

$$\frac{Q_R}{Q_I} = \frac{A_R \cdot F_R(L_R)}{A_I \cdot F_I(L_I, R_I)} = \frac{A_R \cdot F_R\{\bar{L}(t) - L_I(P)\}}{A_I \cdot F_I\{L_I(P), R_I(P)\}}, \tag{11}$$

we obtain the S-curve in the diagram.

For given values for $\bar{L}(t)$, A_I and A_R, this curve has a positive slope, which can be shown in the following way. If we differentiate (3) and (10) we obtain

$$\frac{\partial^2 Q_I}{\partial R_I \partial L_I} \cdot dL_I + \frac{\partial^2 Q_I}{\partial R_I^2} \cdot dR_I = dP; \tag{12}$$

$$\frac{\partial^2 Q_I}{\partial L_I^2} \cdot dL_I + \frac{\partial^2 Q_I}{\partial R_I L_I} \cdot dR_I = \frac{dQ_R}{dL_R} \cdot dP - P \cdot \frac{d^2 Q_R}{dL_R^2} \cdot dL_I. \tag{13}$$

Solve dR_I from (12) and substitute in (13):

$$\left[\frac{\partial^2 Q_I}{\partial R_I^2}\right]^{-1} \cdot \left[\frac{\partial^2 Q_I}{\partial L_I^2} \cdot \frac{\partial^2 Q_I}{\partial R_I^2} - \left(\frac{\partial^2 Q_I}{\partial R_I \partial L_I}\right)^2\right] dL_I + P \cdot \frac{d^2 Q_R}{dL_R^2} \cdot dL_I = \left[\frac{dQ_R}{dL_R} - \frac{\dfrac{\partial^2 Q_I}{\partial R_I \partial L_I}}{\dfrac{\partial^2 Q_I}{\partial R_I^2}}\right] \cdot dP. \tag{14}$$

The expression within the larger parenthesis on the left side of the equality is the Hessian for the production function of the industrial sector. Since this function, according to the assumptions, is homogeneous to the first degree, the Hessian is identically, i.e. for all values of L_I and R_I, equal to zero. From (14), therefore, we obtain

$$\frac{dL_I}{dP} = P^{-1} \cdot \frac{\dfrac{dQ_R}{dL_R} - \dfrac{\dfrac{\partial^2 Q_I}{\partial R_I \partial L_I}}{\dfrac{\partial^2 Q_I}{\partial R_I^2}}}{\dfrac{d^2 Q_R}{dL_R^2}} < 0^1 \tag{15}$$

which together with (12) gives

$$\frac{dR_I}{dP} = \frac{1 - \dfrac{\partial^2 Q_I}{\partial R_I \partial L_I} \cdot \dfrac{dL_I}{dP}}{\dfrac{\partial^2 Q_I}{\partial R_I^2}} < 0.^1 \tag{16}$$

The slope of the S-curve is obtained by derivation of (11) with respect to P:

$$\frac{dS}{dP} = \frac{-\dfrac{dQ_R}{dL_I} \cdot \dfrac{dL_I}{dP} \cdot Q_I - \left(\dfrac{\partial Q_I}{\partial L_I} \cdot \dfrac{dL_I}{dP} + \dfrac{\partial Q_I}{\partial R_I} \cdot \dfrac{dR_I}{dP}\right) \cdot Q_R}{Q_I^2}. \tag{17}$$

Closer scrutiny of this expression reveals that when production functions have normal qualities, (15) and (16) guarantee that

[1] $\frac{dL_I}{dP}$ and $\frac{dR_I}{dP} < 0$ is determined by the fact that $\frac{dQ_R}{dL_R}$ and $\frac{\partial^2 Q_I}{\partial R_I \partial L_I} > 0$ and that $\frac{\partial^2 Q_I}{\partial R_I^2}$ and $\frac{d^2 Q_R}{dL_R^2} < 0$.

$$\frac{dS}{dP} > 0, \tag{18}$$

i.e. that the supply curve S in the diagram increases with increasing P.

Does the intersection between the S and D curves now represent an equilibrium position? For this price relation, the ratio between supplied quantities of raw and manufactured goods is equal to the corresponding ratio for the demanded quantities. Consequently we could have a situation where the relative surpluses in both markets were equal in magnitude. The mere existence of a point of intersection, therefore, does not guarantee an equilibrium position. However, since we have only two goods, the demand surpluses in both markets —assuming the validity of Say's Law—must be numerically equal but opposite in sign. In order for the relative demand surpluses to fulfill these conditions simultaneously they must also equal ± 0. The intersection between the S- and D-curves implies, thus, that the price relation (P) is in equilibrium.

The position of the curves in the diagram, as appears from (5) and (11) are dependent on the exogeneously determined productivity parameters A_I and A_R.[1] The position of the supply curve is further decided by total available resources $\bar{L}(t)$. The growth process, therefore, tends to shift the position of the curves in the diagram. We can study these shifts by determining dD/dt and dS/dt, respectively, with the constraint that the price relation, P, remains unchanged.

For the demand curve we obtain from (5)

$$\left[\frac{d\frac{R_I}{Q_I}}{dt}\right]_{P=\text{const.}} = -\{A_I\}^{-2}\cdot\{f_I(r)\}^{-1}\cdot\frac{dA_I}{dt} - \{A_I\}^{-1}\{f_I(r)\}^{-2}\cdot\frac{df_I}{dr}\cdot\left[\frac{dr}{dt}\right]_{P=\text{const.}} \tag{19}$$

To determine $\left[\frac{dr}{dt}\right]_{P=\text{const.}}$ we use

$$\frac{\partial Q_I}{\partial R_I} = A_I\cdot\left[f_I(r) - r\cdot\frac{df_I}{dr}\right] = P. \tag{20}$$

By differentiating (20) and asserting that $dP=0$ we obtain

$$\left[\frac{dr}{dt}\right]_{P=\text{const.}} = \frac{f_I(r) - r\cdot\frac{df_I}{dr}}{r\cdot\frac{d^2f_I}{dr^2}}\cdot\frac{dA_I}{A_I\,dt} < 0.\text{[2]} \tag{21}$$

Substituting (21) in (19):

[1] By assuming that technological development has the special form of $A_I\cdot f_I$, the analysis has been limited to what is commonly referred to as a "neutral technological development".

[2] The numerator equals $A_I^{-1}\cdot(\partial Q_I/\partial R_I)$ and is therefore positive, while d^2f_I/dr^2 is negative, which, with a positive value for $dA_I/A_I\,dt$ gives $[dr/dt]_{P=\text{const.}} < 0$.

$$\left[\frac{d\dfrac{R_I}{Q_I}}{dt}\right]_{P=\text{const.}} = -\{A_I\cdot f_I(r)\}^{-1}\left[1+\frac{df_I}{f_I(r)dr}\cdot\frac{f_I(r)-r\cdot\dfrac{df_I}{dr}}{r\cdot\dfrac{d^2f_I}{dr^2}}\right]\frac{dA_I}{A_I\,dt}$$

$$= -\{A_I\cdot f_I(r)\}^{-1}\cdot\left\{1-\frac{1}{e}\right\}, \tag{22}$$

where (e) designates the elasticity of substitution between raw materials and labour in industrial production.[1] The D-curve shifts upwards (to the right) in the diagram if the elasticity of substitution is less than one, and downwards (to the left) if (e) is greater than one. Only if the elasticity of substitution equals one will the D-curve be uninfluenced by technological development.[2] Thus, we cannot determine the nature of the shift in the D-curve even in the case of neutral technological development, without knowing the relevant qualities of the production function in the industrial sector.

Its also appears from this, that for production functions with variable elasticity of substitution, the "shift" of the D-curve produced by technical change is ambiguous; (dD/dt) will be positive for that part of the production function, where $e<1$ and negative, where $e>1$. Obviously this is a situation, where the D-curve is turned around one point. And this point is obtained as a solution to (2) above for the specific value of r, which—with the actual production function—gives $e=1$.

The effects of economic growth on the position of the supply curve are considerably more difficult to derive since the expressions in this case are so complicated that the conditions for shifting the curve in one direction or the other, are difficult to interpret; and hence the possibility to give them an intuitively understandable content is almost non-existent. We have, therefore, only sketchily shown the factors which determine the shift of the supply curve.

It appears that the problem may be more simply treated if L_I, instead of R_I, is extracted from the production function (1). Then, we obtain, instead of (11)

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[1] The elasticity of substitution (e) is defined as:

$$e=\frac{d\left(-\dfrac{dL_I}{dR_I}\right)}{dr}\cdot r\cdot\left(-\frac{dL_I}{dR_I}\right)^{-1}, \tag{22 a}$$

where $-(dL_I/dR_I)$ in the usual way signifies the marginal rate of substitution between R and L.

For the marginal rate of substitution, we know that

$$-\frac{dL_I}{dR_I}=\frac{\partial Q_I}{\partial R_I}\cdot\left(\frac{\partial Q_I}{\partial L_I}\right)^{-1}=\left[f(r)-r\cdot\frac{df}{dr}\right]\cdot\left(\frac{df}{dr}\right)^{-1}. \tag{22 b}$$

If we differentiate the last member of (22 b) with respect to r and the result is substituted in (22 a) it appears that $(-e)^{-1}$ is equal to the second term within the larger parentheses in (22).

[2] As we know, the always "well-behaved" Cobb–Douglas function has this property.

$$\frac{Q_R}{Q_I}=\frac{A_R\cdot F_R\{\bar{L}(t)-L_I\}}{A_I\cdot L_I\cdot h_I\left(\frac{1}{r}\right)}. \tag{11 a}$$

We begin with the simpler case of an increase only in resources, i.e., growth without any productivity changes. We know from earlier treatment that the term $1/r$ in (11 a) remains unchanged if there is no technological development in the I-sector. This can be seen from the fact that $(dr/dt)=0$ if $dA_I/A_I dt=0$ in (21). The changes in Q_R/Q_I are, therefore, determined wholly by the changes in L_I and L_R.

The effects on allocation of an increase in available resources are obtained by the differentiation of (10) keeping in mind that $\frac{d\frac{1}{r}}{dt}$ and dP/dt both equal zero. We then get

$$\frac{dL_I}{dt}=\frac{d\bar{L}}{dt}, \tag{23}$$

which implies that

$$\frac{dL_R}{dt}=\frac{d\{\bar{L}(t)-L_I\}}{dt}=0. \tag{24}$$

If $d\bar{L}/dt$ is positive, i.e. if we have an increase in total available resources, it appears from (11 a) that the S-curve in the diagram will be shifted upwards and to the left. At this new position, for every given price relation, a greater number of manufactured goods per unit of raw material will be supplied than before.

The effects of technological development at a given level of resource supply are somewhat more complicated. For the derivation we have used the fact that

$$\frac{\partial Q_I}{\partial L_I}=A_I\cdot\frac{df_I}{dr}. \tag{25}$$

Substitute (25) in (10):

$$A_I\cdot\frac{df_I}{dr}=P\cdot A_R\cdot\frac{dF_R}{dL_R}. \tag{26}$$

If we now differentiate (26), as before, with $dP=0$, we get

$$\left[\frac{df_I}{dr}\cdot\frac{dA_I}{dt}+A_I\cdot\frac{d^2f_I}{dr^2}\cdot\frac{dr}{dt}-P\cdot\frac{dF_R}{dL_R}\cdot\frac{dA_R}{dt}\right]dt=-P\cdot A_R\cdot\frac{d^2F_R}{dL_R^2}dL_I. \tag{27}$$

We then substitute dr/dt in this expression according to (21), after which dL_I/dt can be solved:

$$\left[\frac{dL_I}{dt}\right]_{P=\text{const.}}=-A_I\cdot\left[A_R\cdot P\cdot r\cdot\frac{d^2F_R}{dL_R^2}\right]^{-1}\cdot\left[f_I\cdot\frac{dA_I}{A_I dt}-r\cdot\frac{df_I}{dr}\cdot\frac{dA_R}{A_R dt}\right]. \tag{28}$$

This expression offers a complete description of the effects of technological development on the allocation of resources: $dL_R = -dL_I$ since $\bar{L}(t)$ is given. The factor preceding the parenthesis (including the minus sign) is always positive since $d^2F_R/dL_R^2 < 0$. We know furthermore that $f_I > r \cdot (df_I/dr)$ for all values of (r), since

$$f_I - r \cdot \frac{df_I}{dr} = A_I^{-1} \cdot \frac{\partial Q_I}{\partial R_I} > 0. \tag{29}$$

If the development is characterized by the fact that

$$\frac{dA_I}{A_I\,dt} \geqslant \frac{dA_R}{A_R\,dt},^{1} \tag{30}$$

then the term in the parenthesis in (28) must be positive for all values of (r), which in turn means that dL_I/dt is positive. We obtain, in this manner, a continual reallocation of existing resources from the R sector to the I sector as long as the productivity increase in the R sector is not relatively greater than in the I sector.

What happens now if the rise in productivity in the R sector exceeds that in the I sector? If we, for two given values for $dA_R/A_R\,dt$ and $dA_I/A_I\,dt$, solve the equation

$$\frac{dA_R}{A_R\,dt} \cdot \left[\frac{dA_I}{A_I\,dt}\right]^{-1} = f_I(r) \cdot \left[r \cdot \frac{df_I}{dr}\right]^{-1}, \tag{31}$$

with respect to (r), it is clear that for this value (r), the term in the parenthesis in (28) equals zero. This in turn means that dL_I/dt becomes equal to zero. For other values of (r), given changes in productivity lead to either positive or negative values for dL_I/dt.

This situation can most simply be described by the use of a diagram which shows the optimal allocation to the I sector. As was shown above, L_I is a function of the price relation $P((dL_I/dP) < 0$ according to (15)).

The solidly drawn curve designates the optimum allocation before the increase in productivity, while the point-dashed curve describes the same relation after the change. Since there exists a monotonic relation (eq. 3 above) between r and P, the solution to (31) represents a point in the above diagram. This is designated by $P_I L_I$, and comprises the point of intersection of the two curves, since dL_I/dt equals zero at that point. To the right of $P_1 L_1$, i.e. for higher values of P, $(dL_I/dt) > 0$. While for lower values of P, $(dL_1/d1) < 0$. The shift from the solidly drawn curve to the dashed curve represents a tech-

[1] Actually this condition applies only for the class of production functions which are characterized by the fact that marginal productivity for one factor approaches zero when the usage of the other factor approaches zero. To this class belongs the Cobb-Douglas function. For other types of production functions, instead of (30) we should apply

$$\frac{dA_I}{A_I dt} \geqslant \frac{dA_R}{A_R\,dt} + \mu, \tag{30 a}$$

for $(dL_I/dt) > 0$. μ designates a positive number, the size of which is determined by the value for $(\partial Q_I/\partial R_I) \cdot A_I^{-1}$ when L_I approaches zero.

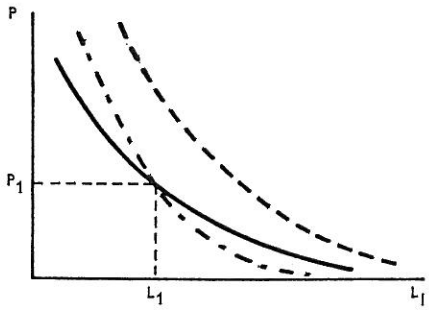

Fig. 3.

nological development which for all values of P leads to $(dL_I/dt) > 0$. In other words, we have here the case which was characterized above by the fact that $(dA_R/A_R\,dt) \leqslant (dA_I/A_I\,dt)$.[1] Now, if we let the difference between the relative increases in productivity $[(dA_R/A_R\,dt) - (dA_I/A_I\,dt)]$ assume successively higher (positive) values—for given production functions—the point, at which the curve turns around, is shifted progressively to the left in the diagram along the solidly drawn line. An increasingly larger part of the area concerned thus displays negative values for dL_I/dt.

We can now study the effects of technological development on the supply curve by differentiating (11 a)

$$\left[\frac{d\dfrac{Q_R}{Q_I}}{\dfrac{Q_R}{Q_I}\,dt}\right]_{P=\text{const.}} = \frac{dA_R}{A_R\,dt} - \frac{dA_I}{A_I\,dt} - \left[\frac{dF_R}{F_R\,dL_R} + L_I^{-1}\right]\left[\frac{dL_I}{dt}\right]_{P=\text{const.}} - \frac{dh_I}{h_I\,d\dfrac{1}{r}} \cdot \left[\frac{d\dfrac{1}{r}}{dt}\right]_{P=\text{const.}} \tag{32}$$

The expressions $[(dF_R/F_R\,dL_R) + L_I^{-1}]$ and $\dfrac{dh_I}{h_I\,d\dfrac{1}{r}}$ are always positive, which is also the case with $\left[\dfrac{d\dfrac{1}{r}}{dt}\right]$, whose numerical value is dependent upon $dA_I/A_I\,dt$ according to (21).[2] On the other hand, the sign $[dL_I/dt]$ is, as has been shown above, dependent upon the relation between the productivity changes in both sectors. By substituting in (31) according to (21) and (29) we would obtain the total effect of technological development on the supply ratio Q_R/Q_I. This will not be attempted here, however, since one obtains expressions which will unduly complicate a more easily understood interpretation.

[1] If $(dA_R/A_R\,dt) = (dA_I/A_I\,dt)$, the curves will coincide at that value of (r) which satisfies the equation $(\partial Q_I/\partial R_I) = 0$. (Cf. n. 1, p. 23.)

[2] $\dfrac{d\dfrac{1}{r}}{dt}$ must be positive since according to (21), dr/dt is negative.

Instead the effects of technological development will be inferred by starting with an imaginary case of no technological development in the R sector $((dA_R/A_R\,dt) = 0$; but $(dA_I/A_I\,dt) > 0)$. As we saw earlier, in this case $(dL_I/dt) > 0$ and all terms in (31) then become positive. dS/dt will thus be negative for all values of L_I and the S curve shifts upwards to the left throughout its entire length.

If we then increase $dA_R/A_R\,dt$ at a given value for $dA_I/A_I\,dt$, the following occurs to (31):

a) a positive term, $dA_R/A_R\,dt$, is introduced;

b) as we have already seen, dL_I/dt approaches zero and may become negative.

In the situation where $(dA_R/A_R\,dt) = (dA_I/A_I\,dt)$, the two first terms in (31) will clearly cancel each other out. From the foregoing we also know that dL_I/dt in this case is greater than or equal to zero, and therefore dS/dt definitely has a negative sign.

As $dA_R/A_R\,dt$ increases in relation to $dA_I/A_I\,dt$, we obtain two positive tendencies, $\frac{dA_R}{A_R\,dt}$ and $-\left[\frac{dF_R}{F_R\,dL_R} + L_I^{-1}\right]\frac{dL_I}{dt}$, which counteract the negative, $-\frac{dA_I}{A_I\,dt}$ and $-\frac{dh_I}{h_I\,d\frac{1}{r}} \cdot \frac{d\frac{1}{r}}{dt}$ for some portion of the supply curve S. This means that, as a consequence of technological development, the curve turns around a certain value for Q_R/Q_I, and thus lies above the original S-curve on one side of the point, and below on the other side.

In summary we can say that the effects of economic growth on the supply curve are extremely complicated. Consequently, we must be satisfied with conclusions of a more general nature. Firstly, the supply curve will be shifted upwards to the left in its entirety as long as technological development in the raw material sector does not proceed at a faster rate than in industrial production. As soon as technological development in the R-sector exceeds the progress in the I-sector, however, the "shift" will no longer be unanimous; instead, the curve will "turn" around at a certain value for Q_R/Q_I.[1] One part of the new supply curve will thus lie below the old one, while another part will lie above. The greater the differences between the productivity rises, the greater will be the part of the new curve lying below and to the right of the old curve.

Finally, it should be reiterated that the effects of a change in the total available resources are unanimous. The S-curve, in its entirety, shifts upwards (to the left) in the event of an increase in resources.

[1] Cf., however, note 1 p. 23.