A Survey of Intermediate Products in

International Trade

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April, 1974

Economics 555
International Economics – Trade
Submitted to:
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I.   Introduction

In his excellent paper, "The Pure Theory of International Trade: A Survey," Jagdish Bhagwati states that, at that time, one of the central limitations of trade theory was "the negligible dent made so far by intermediate and capital goods in the theoretical models employed by the analysis of international trade" (2). Incorporating intermediate goods into trade models is important because the bulk of international trade is in intermediate goods. This fact leads to an obvious question. Will the conclusions of traditional international trade theory be vitiated by the introduction of intermediate goods?

As Bhagwati saw it, the existing analysis obtained in this direction would probably survive the required reformulation of the models. The main purpose of this paper is to verify the accuracy of Bhagwati's conjecture. Many articles have since been published which explicitly recognize the production and trade of intermediate and (produced) capital goods. Some of the results support the robustness of the traditional trade models; other results negate or modify the traditional propositions. As we shall see, the conclusions obtained depend upon the exact specification of the model employed.

The paper proceeds as follows. In section II we will analyze models based on one primary factor and two (or more) intermediate/final goods, while in section II we will consider models based on two primary factors and two intermediate/final goods. Section IV examines the implications when the intermediate goods are used solely as inputs in the production of other products. In section V we will summarize the proffered models and results, attempt to reach some general conclusions, and suggest further possible directions of research.

II.   Ricardian Models

Basically, there are two different types of models usually employed in international trade theory. The first type of model attributes the presence of trade to different productive processes in different countries due to "climate". The second type of model assumes the productive processes are identical between countries. Here, the presence of trade is attributed to differences in tastes and factor endowments. Models of the first class, or Ricardian models, assume that labor is the only ultimate factor. The productive process evolves through one or more stages until the final product emerges. It is the first type of model which will be considered in this section.

Lionel McKenzie, in his paper "Specialization and Efficiency in World Production," was the first author to realize that the introduction of trade in intermediate products would involve changes in the classical analysis. Using the recently developed methods of activity analysis and linear programming, McKenzie examined specialization and efficiency in a general Mill-Graham model. He concurred with Stanley Reiter's observation in "Trade Barriers in Activity Analysis" that trade in intermediate products would enlarge the world production-possibility set. However, the use of Samuelson's substitution theorem is lost.

In the paper "Abstract of a Theorem Concerning Substitutability in Open Leontief Models," Paul Samuelson showed that

> if labor was the only unproduced factor for an economy in which each production function is homogeneous and has but one product; then, assuming that production is efficient, each good will be produced by a single process and the rate of transformation between labor and any good will be constant. Thus, the economy may be treated as though its processes were completely integrated (McKenzie 166).

As long as intermediate products were not traded, it was possible to assume that each country used the same productive process to produce a given good. If trade is allowed, the imports of intermediate products play the role of another factor of production. The most efficient productive process for a given country will then depend on the prices of intermediate products which will vary with final demand (McKenzie 179). It can no longer be known in advance, for a given country, which of its possible production processes a given industry will use.

In "A Survey of the Theory of International Trade" John Chipman writes that the only exception is

> the case where one country is so large that its prices under autarky rule the roost under trade … But even in this case, the Samuelson substitution theorem applies only to that one country, and furthermore we cannot know in advance whether a particular country's cost will dominate international prices (510).

McKenzie's algorithm for determining efficient specializations—the world efficiency locus is found by finding the efficient solutions for each country, at a given price constellation, and adding them up—breaks down. (177-179). Another

result is that the pattern of efficient specializations may reverse from the no-trade to the trade case.

As we have noted, McKenzie was working within the framework of linear activity analysis, and was not concerned with what the transformation surfaces would look like if the production function allowed substitution between inputs. In "Intermediate Products and Differential Tariffs: A Generalization of Lerner's Symmetry Theorem," Ronald McKinnon analyzed the gains from trade and the production possibility curve in the context of an intermediate good model which allows substitution in production. Like all models in this section, McKinnon assumed that there is a single-factor, labor. But now, each of the two products, X_1 or X_2, can be produced in variable proportions from labor and the other product used as an intermediate good.

The model can be written as follows:

$$X_1 = f_1(X_{21}, L_1) - X_{12},$$

$$X_2 = f_2(X_{12}, L_2) - X_{21},$$

$$L = L_1 + L_2,$$

where

X_i = net output of product i,

f_i = linear homogeneous production function

for industry i whose gross output is X_i,

L_i = labor used in industry i,

X_{ij} = the amount of X_i used in the jth industry.

Let f_j^* be the total product curves for industry j = 1,2. That is f_j^* is equivalent to the output of industry j when industry j makes use of the total available labor supply. The set of all convex combinations of f_1^* and f_2^* is equivalent to the set of all possible production points and the production possibility curve is the locus of al "outer" boundary points as shown in the Figure 1.

McKinnon gives the following approximate account of this diagram in which all axes represent positive numbers.

The straight-line BE … represents the usual linear transformation curve for the single factor case where there is some gross output of both commodities. At point $B = (B_1, B_2)$, gross output of X_1 is just zero and imports of $X_1 = X_{12} = B_1$ are required to sustain net production of $X_2 = B_2$ – the only net output of the economy. The reverse is true at point E where all the labor

Figure I
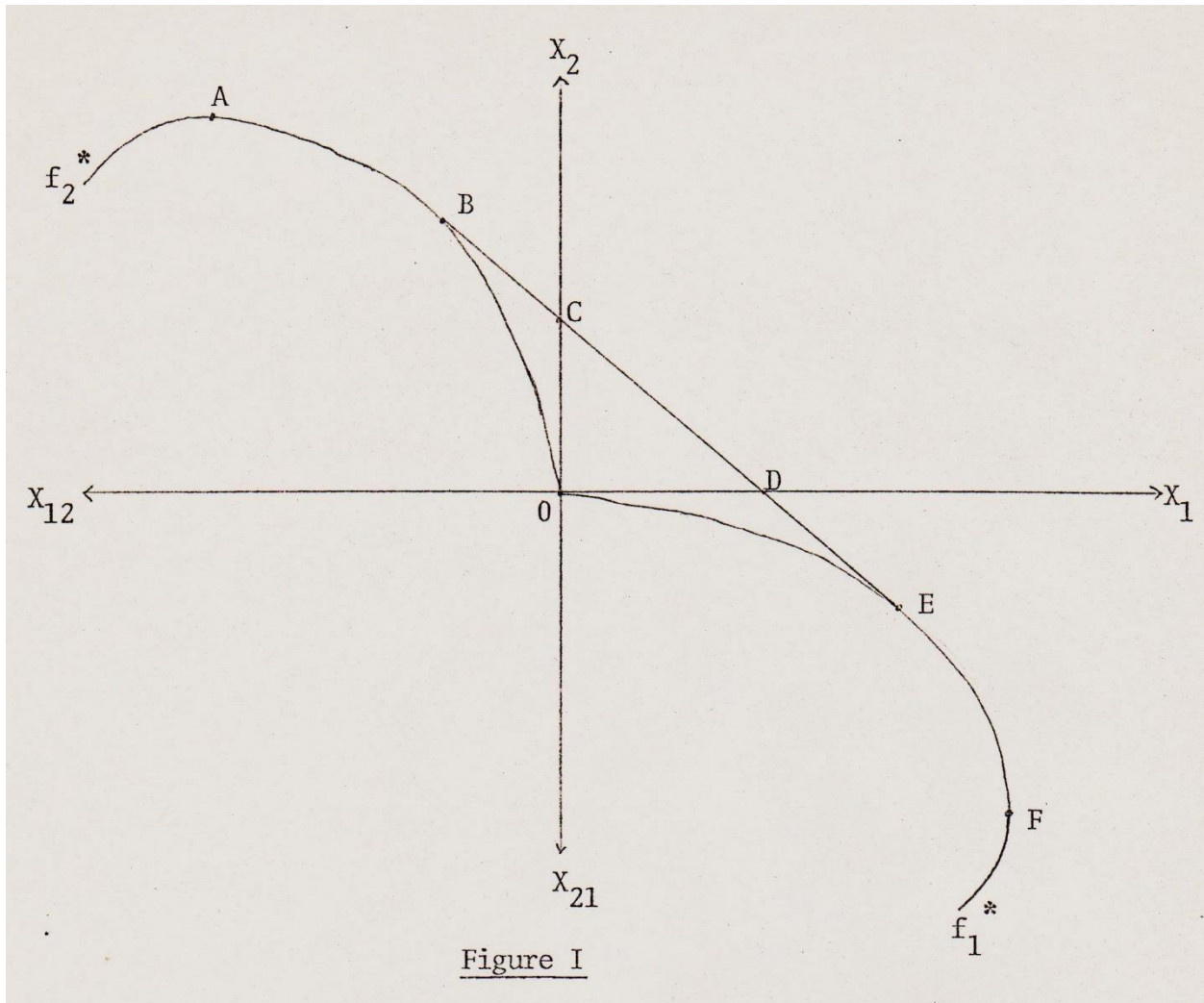
resources are devoted to the gross production of X_2 alone. In a closed economy, net production must be non-negative and be restricted to the line segment CD in the first quadrant. However, such a restriction need not apply in an open economy. For example, imports of X_1 enable production to take place along CB or BA. … (Furthermore,) along the curved segment BA, there is no domestic gross output of X_1; the fixed labor supply is totally

committed to X_2, and the optimal gross production activity changes toward more intensive use of the imported intermediate input as one moves to the left (602).

With the use of the above diagram, it is possible to examine how taking explicit account of the possibility of trade in intermediate goods will affect the gains from trade. Here we will follow the analysis of James Melvin, "Intermediate Goods, the Production Possibility Curve, and Gains from Trade," who considered not only the gains from trade of the entire world, but also the possible gains or losses from trade for the individual country.

Melvin considered two worlds. In the first world, intermediate goods can be both traded and used in production. In the second world, intermediate goods cannot be traded. With respect to Figure I, each country in the first world has a convex production possibility curve of type ABCDEF, while each country in the second world has a linear production possibility curve of type CD. Melvin constructed Edgeworth production boxes from these curves and compares the total world consumption sets for the two situations.

Using this geometrical technique, it is easy to show as many besides Melvin have shown, that the world consumption (or production) set is larger when trade in intermediate goods is allowed. However, even though the world consumption set is larger in the intermediate good case, it is possible to devise examples for which both countries need not gain.

For example, if one country is very large relative to the other, then the only price ratio consistent with efficient world production can be the price ratio equal to the straight-line portion of the large country's production possibility curve—BE in Figure I. The world's price ratio, in this case, is unique and is independent of demand conditions and since consumption for both countries must take place at some point on the world's price ratio, the large country cannot possibly gain from trade. Thus, the introduction of intermediate products can substantially complicate the analysis of who gains from trade, and the conclusion derived in the no-trade case need not apply without modification (147-151).

McKinnon also generalized Abba Lerner's symmetry theorem in his 1936 Economica paper that an *ad valorem* import tariff has same effect as an export tax, to the case where there is trade in intermediate products. The economy he considers is small with respect to the rest of the world, so that the foreign currency

prices of tradeable goods are fixed. The country trades in three goods: an exportable, importable "one" – imports are taxed at rate t; and importable "two' which can enter duty free.

Under "reasonable" conditions McKinnon showed that:

1. Levying an *ad valorem* tariff (a percentage of value or a monetary amount per physical unit) on the foreign price of one class of imports is equivalent to taxing exports as a per cent of their domestic price, together with subsidizing previously untaxed imports as a per cent of their domestic price at the same *ad valorem* tax rate t;
2. Raising t has the 'normal' effect of reducing exports and increasing untaxed imports only if certain complementarity (substitution) conditions among the demand and supply functions hold;
3. There is an interesting economic interpretation of the concept of complementarity in supply relating to the use of intermediate products and the input-output structure of the economy which does not appear to be explicit in the standard Hicksian formulation. For example, if the untaxed importables main use is as an intermediate input in the production of exportables, then the two importables will appear as complements in production. Such complementarity tends to reverse the 'normal' impact on exports and untaxed imports of raising t;
4. The participation of domestic primary factors per unit of gross output in the protected industry is likely to decline significantly relative to the use of imported intermediates, as t is raised. This result significantly affects the validity of 'infant' industry and foreign exchange saving arguments supporting protection and is one important reason … for the proliferation of domestic context requirements in protected industries. Furthermore, these general equilibrium repercussions on domestic factor prices tend to have significant implications for simple partial equilibrium concepts of 'effective protection given to domestic value added', as have recently been proposed.

III.   Heckscher-Olin Models

The models in the last section were typified by the assumptions of one-primary factor and two or more intermediate / final goods. In this section we will consider models of the two-factor and two- intermediate good Heckscher-Ohlin type. These

models can further be classified according to whether they assume the intermediate products are used in the production of the final goods in fixed or in variable proportions.

We shall see that the explicit recognition of intermediate goods does not have a crucial effect on some basic theorems, e.g., the factor-price equalization theorem (free trade in goods will result in an equalization of factor prices between countries) and the Stopler-Samuelson theorem (a rise in the unit relative price of a produced good will increase the unit price of the factor used intensively in the production of the good). However, other theorems cannot be proven without qualifications.

In his article, "Variable Factor Proportions and Inter-Industry Flows in the Theory of International Trade," Jaroslav Vanek noted that the analysis of international trade was usually carried out in two distinct compartments. In the first compartment it is assumed that each of a certain number of products is produced within the economy from a number of substitutable primary productive factors and inter-industry flows are rarely mentioned.

In the second compartment it is assumed that "all or most products of the economy flow from one industry to another as materials, and only some proportion of total output reaches final demands, (and) only one scarce factor is assumed." This compartment contains the input-output models where input-output coefficients are constant.

Vanek attempted to resolve this "dichotomy between the input-output analysis and the more traditional 'continuous' theory of general equilibrium." The model he considers is as follows:

$$1) \ X_1 = f_1(L_1, K_1),$$
$$X_2 = f_2(L_2, K_2),$$
$$L = L_1 + L_2,$$
$$K = K_1 + K_2;$$
$$2) \ x_1 = X_1 - a_{12}X_2,$$
$$x_2 = X_2 - a_{21}X_1.$$

The x_i represent net outputs, the X_i are gross outputs and the a_{ij} represent the input of the it^{th} product per unit of the jth product.

The first point to note is that while Vanek allows variable proportions between primary factors, the intermediate products are still used in fixed proportions, the a_{ij}. The gross production possibility curve can be constructed from 1) and can be thought of as the total amount of X_1 and X_2 that could be produced if intermediate inputs were not required for production. It is the outer curve In Figure II. Here again the axes represent positive numbers.
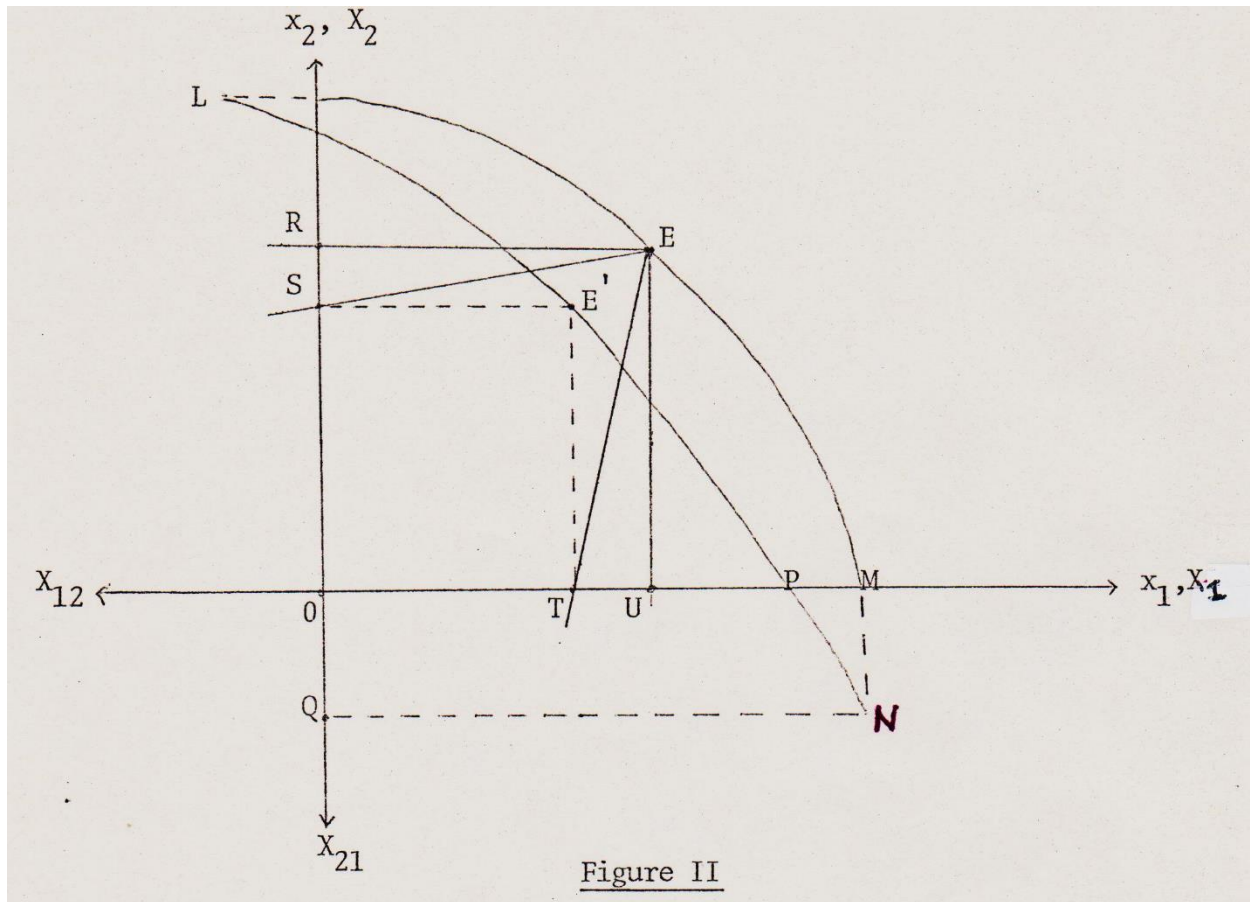
Figure II

Robert Warne in "Intermediate Goods in International Trade with Variable Proportions and Two Primary Inputs" examined and explained Vanek's approach as per Figure II. The net production possibility curve can be constructed from the gross curve. If the economy produces at E, RS of X_2 ($a_{21}OU$) and TU of X_1 ($a_{12}OR$) are used up in production, and thus the amount delivered to final demand is represented by E'. Warne's diagram of the production possibility curves differs from Vanek's, in that Warne allows the possibility of a negative net production of

one good. The required amount imported is represented by the X_{ij} axes. By drawing lines 0L and 0N, we get their slopes as $-a_{21}$ and $-1/a_{12}$, respectively.

It is well known that the slopes of the gross curve at its different points, that is, the marginal rates oft transformation between X_1 and X_2, express relative product prices under perfectly competitive conditions.

Vanek showed that the same relation holds for the net curve, LE'N. By differentiating totally the above equations, solving for dx_2/dx_1 and making the use of the fact that under perfectly competitive conditions profit in each industry will be maximized if the price of capital is equal to the marginal value-added product of capital, it is possible to determine that

$$dx_2 / dx_1 = - P_1 / P_2.$$

Using the diagram developed above and the relation between the net curve and the ratio of product prices, Vanek generalized the factor-price equalization theorem. The usual assumptions—identical production functions for identical products, unit homogeneous production functions, free trade, zero transportation costs, both products produced in both countries, and uniform factor-intensiveness—are retained. He showed that whether different products are produced from primary productive factors as well as from other materials, employed in fixed proportions to output, the factor-price equalization theorem holds (135-138).

Vanek also generalized the Hecksher-Ohlin theorem to the case where interindustry flows are permitted. If the assumption that the demand conditions are similar between the two countries is added to the above list, it can be shown that a country relatively better endowed with a given factor will tend to export a relatively greater proportion of products employing the abundant factor intensively, and will specialize in such products.

For example, the country which is better endowed with capital will produce a greater gross output of the capital-intensive industry relative to the labor-intensive industry than the other country. However, "the degree of comparative specialization of the capital abundant country with respect to net outputs must be even stronger, because, with an increased gross output of the capital-intensive product, additional gross output of the labor-intensive product must be withdrawn from final consumption to serve as a material input" (140-141).

In his article mentioned above, Warne generalized (actually combined) the models of Melvin and Vanek by allowing intermediate products to be used in variable proportions in the two-factor model. The net production possibility curve in this case is very similar to that in Figure I. But now the curve will lie above the straight line BE and is everywhere concave to the origin. In the one-primary-factor model, the linear portions of the net production possibility curves ensure

> net specialization in at least one country at all world price ratios so that prohibition of trade in intermediate products will always decrease total output. In the more general model, however, a large portion of the world consumption curve may be the same whether or not negative net output of a good is possible.

The most complete and the most rigorous investigation of the various problems arising from the presence of intermediate goods is that of Winston Chang and Wolfgang Mayer, "Intermediate Goods in a General Equilibrium Trade Model." They examine a simple two-good general equilibrium model in which a proportion of the output of each industry is employed as an input in the other industry. Unlike Vanek, Chang and Mayer allow for relative changes in the input coefficients of the intermediate products. Further, they place greater emphasis on the distinction between net and gross outputs and observe that each output concept can serve quite distinct purposes.

For example,

> if one wants to examine the impact of an exogenous change in the production patterns of different industries in a given country, one should look at the resulting changes in gross output. This is especially relevant to the theory of effective tariff protection as well as the theory of technical change and trade. If, on the other hand, one wants to determine how an exogenous change affects the availability of a given commodity for domestic consumption and foreign trade, one observes net output changes (447).

Chang and Mayer consider the following two-sector model. Let a_{ij} be the quantity of factor i used per unit of gross output of commodity j. Then, the full employment constraints are:

$$1) \quad a_{L1}X_1 + a_{L2}X_2 = L,$$
$$2) \quad a_{K1}X_1 + a_{K2}X_2 = K,$$

and net output is given by:

3) $x_1 = X_1 - a_{12}X_2,$
4) $x_2 = X_2 - a_{21}X_1,$

and the equilibrium conditions of perfect competition are:

5) $a_{L1}w + a_{K1}r + a_{21}P_2 = P_1,$
6) $a_{L2}w + a_{K2}r + a_{12}P_1 = P_2,$

where w is the unit wage rate, r is the rental rate on a unit of capital, and P_j is the competitive price of a unit of commodity j.

Totally differentiating 1) and 2) and denoting the fraction of the ith factor used in the jth commodity by U_{ij}, and relative changes by $*$ we get:

7) $X_1^* - X_2^* = (L^* - K^*) / |U| - (U_{L1}a_{L1}^* - U_{L2}a_{L2}^* - U_{K1}a_{K1}^*$
$\qquad\qquad\qquad - U_{K2}a_{K2}^*) / |U|,$

where $|U| \equiv U_{L1} - U_{K1}$, which is positive if the first commodity is labor intensive.

Similarly, from 3) and 4) we obtain relative changes in the ratio of net output:

8) $x_1^* - x_2^* = m(X_1^* - X_2^*) - a_{12}^*X_{12}/ X_1 + a_{21}X_{12} / X_{21},$

where $m = 1 + X_{12} / X_1 + X_{21} / X_2.$

Some interesting results in international trade theory drop out of this model by specifying some parameters. Setting $a_{ij}^* = 0$ in equations 7) and 8) we get, respectively, the gross and net Rybczynski effects (e.g., an increase in L changes the net and gross output). One can also see that if intermediate coefficients are fixed, changes in relative net and gross output are always in the same direction. If intermediate input coefficients are flexible, changes in gross output are related to changes in net output and the changes in the intermediate input coefficients.

Performing the same operation on equations 5) and 6) we obtain the Stoper-Samuelson theorem:

9) $w^* - r^* = (1 - v_{12}v_{21}) (P_1^* - P_2^*) / |v|,$

where v_{ij} denotes the income share of the ith input in the jth industry, and

10) $\quad |v| = v_{L1}v_{K2} - v_{K1}v_{L2}.$

Since $(1 - v_{12}v_{21})$ and $|v|$ are > 0 or < 0 depending on whether the first or second industry is labor-intensive, a relative rise in the labor-intensive product price will bring about a relative increase in the return of labor to that of capital (451).

Chang and Mayer also consider the effects of price changes on net and gross outputs. They find that, as in the case of changes in factor endowments, the net and gross outputs will change in the same direction if the intermediate input coefficients are fixed, but the changes may be in the opposite direction if the input coefficients are flexible. This, of course, has important consequences for the effect of tariffs on industry outputs and for the size of optimum tariffs when intermediate goods are included in the analysis.

IV.   Non-Consumable Intermediate Goods

The feature that all models considered so far have in common is that the intermediate good is also a final good. Raveendra Batra and Francisco Casas, "Intermediate Products and the Pure Theory of International Trade: A Neo-Heckscher-Ohlin Framework," have criticized this feature of these models. They claim that it is not surprising that the traditional theorems hold since the differences between these models and the traditional models is minor. The traditional theorems remain valid because they depend crucially upon the factor-intensity ranking of the traded commodities, and the introduction of intermediate products which are also final products generally does not change this ranking.

Batra and Casas define "pure" intermediate products as those which are produced solely to serve as inputs in the production of final goods. They also observe that in a two-good two factor model,

> where intermediate and final products are identical, one cannot explain the trade in intermediate goods. For this reason, there exists no theory at present which would explain why trade occurs in such goods even though … the bulk of international trade is in intermediate products—produced goods, like raw materials, spare parts, etc., which are solely used as inputs int the production of other products (297).

For the sake of brevity, we will just write down their model, somewhat modified, and then state their basic results. Their economy consists of two primary factors of production, L and K, and three commodities, two final products, X_1 and X_2, and one intermediate good X_3, which is produced or obtained through trade solely to serve as input in the production of the final products.

The full employment constraints are:

1) $a_{L1}X_1 + a_{L2}X_2 + a_{L3}X_3 = L$,
2) $a_{K1}X_1 + a_{K2}X_2 + a_{K3}X_3 = K$.

Let a_{3j} denote the requirement of material input, X_3, per unit of the jth final commodity. The amount of X_3 available as an input equals the amount produced domestically plus the net quantity (positive, zero or negative) available through trade.

Then, the material balance equation is:

3) $X_3 = a_{31}X_1 + a_{32}X_2$.

The equilibrium conditions of domestic and international perfect competition are:

4) $a_{L1}w + a_{K1}r + a_{31}P_3 = P_1$,
5) $a_{L2}w + a_{K2}r + a_{32}P_3 = P_2$,
6) $a_{L3}w + a_{K3}r \quad\quad = P_3$.

Batra and Casas went on to complicate the model by specifying that in some cases a final or the intermediate good was non traded. They also assumed that the intermediate input-output coefficients, a_{3j}, are fixed, while the labor-output and capital-output coefficients depend on the factor prices.

With some complex algebraic analysis, they prove the following theorems.

Theorem 1: If the capital- labor ratio of the intermediate product lies between the other two capital-labor ration, the Rybczynski theorem holds: An increase in the stock of capital, at constant prices, raises the output of the relatively capital-intensive industry (303).

Theorem 2: If a commodity is relatively intensive in the use of the intermediate good, and if the capital-labor ration of that commodity lies between the capital-labor ratio of the intermediate good and that of the other final commodity, the Rybczynski theorem holds (303).

Theorem 3: If the net and gross factor-intensity rankings are identical, the Stopler-Samuelson theorem holds; otherwise, the Stopler-Samuelson theorem may not hold (305).

Theorem 4: If one of the goods is specified as being non-traded (whether it is a final or an intermediate good), the international exchange of the other two will

follow the Heckscher-Ohlin dictum if the capital-labor ratio of the non-traded good lies between the capital-labor ratios of the other two goods (307).

V.	Summary

We have attempted to survey the literature which considers the effect that taking explicit recognition of intermediate goods has on the traditional trade theorems. The models which incorporate intermediate goods are more realistic as the bulk of international trade is precisely in intermediate goods—produced commodities which serve in the production of other commodities.

Results derived from the models in sections I and II tend to support Murray Kemp's observation in The Pure Theory of International Trade and Investment,

> the standard Heckscher-Ohlin model of trade can be extended to accommodate intermediate goods and that … the principal theorems … carry over with only trivial changes.

In this paper we have not considered the implications of trade in intermediate products for effective tariff protection propositions and legislation. Imposing a tariff an intermediate product would increase a domestic firm's cost of producing its final good with the intermediate product. Low tariffs on the imports of this final good could constrain the final good's selling price with consequences for the firm's profit and output.

Trading systems with large flows of intermediate goods, like Canada and the USA, tend to be stable with much of the trade contracted between and within companies. As a result, the optimal tariff from the point of view of the firms established in both countries would be lower. For example, the 1965 Auto Pact removed tariffs on vehicles and parts. By 1982, automobile and parts production had become Canada's largest industry.

In my opinion, Batra and Casas may be overestimating the importance that the recognition of intermediate products has on the traditional trade propositions. The intermediate good in their model is used in fixed proportions in the final goods. Intuitively, it appears that the additional provisions that are needed to make the traditional trade theorems go through will be satisfied if variable proportions are allowed. Thus, although their qualifications may be necessary in the short run, in the long run after all profit maximization adjustments have been may, they may not be required.

In the long run when international trade arbitrage in trade is complete, the factor proportions of the intermediate products, and factor / intermediate proportions of the final goods will have adjusted to take advantage of any changes in factor endowments and / or demand conditions. Thus, one can conjecture the Rybczynski, Stopler-Samuelson, and Heckscher-Ohlin theorems will go through with only trivial modifications. The missing part, of course, is the theory of the dynamic adjustment process.

Batra and Casas, unlike other authors, supply some motivation for the trade in intermediate goods. Trade in intermediate goods occurs in order to take advantage of different factor intensities in the intermediate good relative to the final good. However, because they assume that the intermediate good is used in fixed proportions in the final goods, demand considerations appear less important than one would expect they are in the real world. Trade in intermediate goods, when their proportions can vary in the final goods, occurs in order to take advantage (for the domestic production of final goods) of immobile factors (in their primary form) which occur in relatively differing proportions (quantitatively and qualitatively) in foreign countries.

Perhaps this approach is one way of incorporating Murray Kravis' availability concept, "'Availability' and Other Influences in the Commodity Composition of Trade," into the more traditional trade theories. Traditional trade propositions are concerned with the long run (static) supply determined aspects of trade. On the other hand, Kravis' availability concept is a short run, demand disequilibrium concept. Any disequilibrium dynamic or perhaps even comparative dynamic approach would have to integrate these two approaches using an intermediate good model of international trade.

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