INTERNATIONAL TRADE AND INDUCED INNOVATION

Richard Grabowski*

I

World trade in staple food commodities has been growing very rapidly. One would suspect that given the relative factor proportions of less developed nations, they would have a comparative advantage in the production of primary commodities, of which food staples is one category. In addition, the development and diffusion of new high-yielding varieties (HYVs) of seeds in many of these countries would also lead one to expect that the less developed nations would be reducing their imports of staple food commodities or increasing their exports. However, if one examines Table I it will be seen that exactly the opposite has been occurring. From 1961-1965 to 1973-1977, the net imports of staple foods of developing nations increased nearly five-fold, from 5 to 23 million tons per year. Thus, net imports have risen from 1.5 per cent of developing country production in the mid-1950s to 5 per cent in the mid-1970s. The main growth in exports of staple food commodities has originated in the developed countries, in particular the United States. Thus, it seems that the developed nations are increasingly becoming the main exporters of this type of primary good and the less developed countries are becoming the main importers.

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<td>Developing countries</td>
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<td>Asia</td>
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<td>North Africa/Middle East</td>
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<td>Sub-Saharan Africa</td>
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<td>Latin America</td>
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Source: Adapted from Mellor and Johnston, op. cit., p. 537.

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1. Staple food commodities include cereals, roots, tubers, pulses, groundnuts, and bananas and plantains.
3. ibid, pp. 536-537.
It will be the main purpose of this paper to explain the trends outlined in the previous paragraph. In order to do this, the next section of this paper will present a brief review of the literature concerning theories which attempt to explain the inability of the less developed to reduce their imports or increase their exports of primary commodities in general and staple food commodities in particular. These theories can be classified into those emphasizing the supply side and those emphasizing demand. The attention of this paper will basically be concentrated on the former and thus technical change will be an important factor. In section III the theory of induced innovation will be reviewed and modified in an attempt to develop an explanation for the poor export performance of less developed countries with respect to staple food commodities. Finally, section IV will summarise the paper.

II

Many economists have argued that the poor export performance, in terms of growth of primary product exports, is due to slow growth in demand. For example, Ragnar Nurkse argued that the growth of demand for primary products stemming from the industrialised nations is limited due to low income inelasticities. In addition, the developed nations have tended over time to develop synthetic substitutes for many of the primary products exported by the less developed countries, thus reducing the possibilities for profitable export expansion.4 Raul Prebisch has extended these ideas to argue that the terms of trade will also tend to turn against the less developed countries who are producing primary commodities.5

Irving Kravis disagrees with the view presented above in that he believes that the decline in the primary product export share for the less developed nations, which occurred between 1953 and the late 1960s, cannot be ascribed to unfavourable market or demand conditions. Instead, the declines were greatest for those commodities produced by the developed nations. He believes that it is in these areas that the less developed nations lost market opportunities and these lost opportunities were mainly the result of internal problems of supply.6

The above conclusion is supported by data gathered by a GATT (General Agreement on Tariffs and Trade) study of export performance by the less developed nations, reproduced by Kravis in his article, and adapted for this paper as Table II. In this table, column 4, the world market factor, shows what each group of less developed country’s export performance would have been had there been no change in the market share of the particular products exported. This should thus reflect the effects of world demand for these traditional exports. Column 5 in the same table, the competitiveness factor, shows how each country’s exports

would have changed if total world trade for each particular product had remained constant and only the market shares of different less developed countries allowed to change.\footnote{7}

As can be seen from the table, it would seem that the export success did not depend upon the world market factor, which represents external demand. It was the competitiveness factor that seemed most significant in determining the export success of a nation. In other words, the successful export performance by certain less developed nations resulted from their efforts to increase the market share for their traditional exports and not from favourable demand conditions for these goods. Thus, Kravis concludes that internal supply factors are of greatest importance in explaining the export performance of the less developed countries.

With respect to staple food commodities, it is obvious from the discussion in the introduction to this paper that the demand for this type of primary commodity has been growing rapidly. This growth in demand has stemmed mainly from the less developed countries themselves and is caused by growth in both their per capita incomes and populations. However, as can be seen from Table I, they have not been able to supply their own needs. In other words, this rapid increase in demand has not led to the rapid growth of staple food commodity trade among the less developed nations. Instead the developed nations, in particular the United States, have captured a large share of this trade and this share is growing rapidly. This seems to be the result of problems on the supply side.\footnote{8}

These problems would seem to be directly connected with difficulties in the development and application of new technologies for increasing the output of staple food commodities. In this regard the theory of induced innovation will be of great help and thus in the next section this theory will be briefly reviewed. The model will then be modified and extended in order to explain the trade performance of the less developed nations with respect to staple food commodities.

\footnote{7}{Kravis, \textit{op. cit.}, p. 867.}

\footnote{8}{Meller and Johnston, \textit{op. cit.} pp. 541-542.}
Hayami and Ruttan have developed an induced innovation model of technological change. They have defined technological change as "any change in production coefficients resulting from purposeful resource-using activity directed to the development of new knowledge embodied in designs, materials, or organization." With this definition of technology in mind, Hayami and Ruttan then proceed to develop an induced innovation model based upon the work of Syed Ahmad. I will present a brief summary of Ahmad's theory in the following few paragraphs.

Ahmad developed what he calls a historical innovation possibility curve. This represents an envelope of all alternative isoquants, each representing a given output on various production functions, which the entrepreneur expects to develop with the use of the available innovating skill and time. Ahmad assumes that these innovation possibility curves are neutral and that the cost and time involved in moving from one isoquant to another, both belonging to the innovation possibility curve of the current period, is equal to that required for moving to the innovation possibility curve of the next period. Since this latter curve is always nearer the origin than the innovation possibility curve of the current period, it must be concluded that all of the isoquants belonging to a particular innovation possibility curve, except the one actually chosen, become irrelevant for economic decisions after the choice is actually made.

An analysis of the model will be greatly facilitated through the use of Figure 1. We will assume that the firm is operating at point A an isoquant Uₐ. We will also assume that the firm perceives innovation possibility curve II, which is the envelope of all the possible alternative innovations, two of which are illustrated by isoquants U₁ and U₂, that can be developed with the same amount of research expenditure. Given the input price ratio represented by the slope of line NN, the firm will choose to develop the technology given by isoquant U₁. If the price of factor Y should rise relative to factor X, budget line PP, the firm would then choose to develop the technology given by isoquant U₂ and thus save the more expensive factor Y.

The theory presented above was developed for application to the private sector. Hayami and Ruttan modified it so as to include innovations developed by the public sector because the public sector has played such an important role in agricultural research. They hypothesized that the farmers are induced by shifts in relative prices, to search for technical alternatives which save the increasingly scarce factors of production. They press the public institutions to develop the new technology and, also, demand that

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agricultural supply firms supply modern technical inputs which substitute for the more scarce inputs. Perceptive scientists and science administrators respond by making available new technical possibilities and new inputs that enable farmers to profitably substitute the increasingly abundant factors for the increasingly scarce factors.\textsuperscript{12} In other words, scientists and administrators of public research programmes are assumed to respond to the problems and needs of society, in this case the problems of the rural sector. These social problems and needs are reflected in the input scarcities which individual farmers must deal with.\textsuperscript{13}

As a simple illustration of how the model works, it will be briefly applied to the agricultural development experience of the United States. In Figure 1, X represents fertilizer and Y land. Prior to the 1930s land was relatively abundant relative to labour which induced, according to Hayami and Ruttan, the development and application of mechanical technologies.\textsuperscript{14} However,

\textsuperscript{12} Hayami and Ruttan: \textit{op. cit.}, p. 57.
\textsuperscript{13} \textit{ibid.}, p. 58.
\textsuperscript{14} Mechanical technologies are thought to be labour-saving, land-using. In addition, they generally do not increase yields. For evidence concerning this, see Hans Binswanger: \textit{The Economics of Tractors in South Asia: An Analytical Review}, Agricultural Development Council, New York, 1978.
beginning in the 1930s land became increasingly scarce and fertilizer increasingly abundant, \textit{i.e.}, the price of fertilizer relative to land fell dramatically. In Figure 1, this is represented by a change in the slope of the budget line from NN to PP. As a result of the operation of the inducement mechanism, research was orientated towards the development of biochemical technologies. These technologies involved the development of new seed varieties which were highly responsive to increased application of chemical fertilizers, represented by isoquant $U_2$.\footnote{It is generally thought that this technology is land-saving, labour-using.}

In most of the developed nations land has become increasingly scarce and thus agricultural research budgets have been increasingly allocated towards the development of biochemical technologies, especially high-yielding seeds. Since the bulk of agricultural research occurs in the developed countries, Figure 1 would represent the direction taken in agricultural research in the developed countries in general.

In addition to the research undertaken by the developed countries, a variety of international research centres have been established in the recent past.\footnote{The most well-known of these are International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT).} These centres have generally catered to the needs of the less developed countries. Since most of these countries are generally characterized by a relative scarcity of fertile land, much of the efforts of the international centres have been concentrated on the development of biochemical technologies.

One might conclude that the less developed nations need only borrow the biochemical technologies being created as a result of the research efforts of the developed nations and the international research centres. However, two problems arise. First, biochemical technologies are generally developed with the soil and climatic conditions of the region in which the research is taking place in mind. Thus the HYVs developed will work best with that particular soil and climate, in other types of environments their productivity will be reduced. Thus in Figure 2, isoquant III represents new biochemical techniques available to the developed countries, as a result of their research. However, if the less developed country borrows this technology and applies it in a very different environmental context, isoquant II would represent the effectiveness of this new technology. Thus, even if both the developed and less developed countries faced the same relative input prices, the costs of producing this particular agricultural commodity would fall by a much greater amount in the developed country, whether measured along the capital or labour axis. As a result, other things remaining unchanged, one would expect to find the developed countries exporting more and importing less of this commodity.

However, even if the productivity of the new technology in the less developed country was as high as in the developed country or region in which it was developed, there is a second reason why the cost of production would still fall by a larger amount in the latter relative to the former. This is
due to the fact that relative factor prices are likely to be different in the two regions. More specifically, the cost of fertilizer is likely to be higher in the less developed relative to the developed region or nation. The production of fertilizer is a highly capital intensive process and the cost of capital is relatively lower in the developed than in the under-developed nations. Even if the less developed nation imports all of its fertilizer from a developed country or region, it is still likely that the cost to the farmer in the former is likely to be greater than the cost to the farmer in the latter region. This is due to the fact that the lack of transportation and communication facilities and the low levels of farmer education are likely to make fertilizer more expensive relative to land in the less developed compared to the developed regions or countries.

The implication of the above argument for the costs of producing agricultural commodities can be best illustrated through the use of Figure 3. X and Y are fertilizer and land respectively. I and II represent isoquants before and after the development of a biochemical innovation. The slopes of budget lines AC and GI represent the price of land relative to fertilizer in
the less developed country or region. The slopes of budget lines DF and JL represent the price of land relative to fertilizer for the developed country or region. As can be seen, even if the isoquant after technical innovation is identical for both the developed and less developed country, costs will fall by a larger amount in the former relative to the latter, whether this reduction is measured along the capital or labour axis.

Thus, there would seem to be two reasons as to why trade in staple food commodities is becoming increasingly dominated by the developed nations. First, the bulk of the agricultural research devoted to the development of biochemical innovations in staple food commodities is conducted in the developed countries themselves or in various international research centres. Thus, these techniques were developed so as to be most responsive to the soil and climatic conditions existing in the particular region in which the research takes place. This means that they are much less successful when applied in different regions and circumstances. Second, even if the biochemical technologies were not location-specific, cost differences would still result because of differences in relative input prices. Given the fact that biochemical innovations allow the substitution of fertilizer for land and fertilizer is generally cheaper in the developed relative to under-developed
nations, it follows that the costs of agricultural production would fall by a larger amount in the former relative to the latter.

If the less developed nations are going to expand their role in trade involving staple food commodities, several policy changes must be undertaken. First, increased amounts of resources must be allocated towards the development of biochemical innovations by the less developed nations or regions. This research must be directed towards developing techniques appropriate to each region's climate and soils and also appropriate to each region's relative input prices. Examining Table III, one can see that in the past the poorer nations have allocated very few of their resources to such activities. Second, attempts must be made to ensure the availability of fertilizer and other complementary inputs, such as irrigation, at as low a cost as possible and yet remain consistent with social opportunity cost.

Table III—Investment in Agricultural Research

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<thead>
<tr>
<th>Group</th>
<th>Per capita income ($)</th>
<th>1971 Total</th>
<th>1974 Total</th>
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<tbody>
<tr>
<td>I</td>
<td>1,750</td>
<td>2.48</td>
<td>2.55</td>
</tr>
<tr>
<td>II</td>
<td>1,001-1,750</td>
<td>2.34</td>
<td>2.34</td>
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<tr>
<td>III</td>
<td>401-1,000</td>
<td>1.13</td>
<td>1.16</td>
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<tr>
<td>IV</td>
<td>150-400</td>
<td>0.84</td>
<td>1.01</td>
</tr>
<tr>
<td>V</td>
<td>150</td>
<td>0.70</td>
<td>0.67</td>
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</table>

Source: Adapted from James Boyce and Robert E. Evenson, Agricultural Research and Extension Programs, Agricultural Development Council, New York, 1975, p. 16.

This would involve the expansion of transportation and communication facilities as well as extension services to teach the farmers how effectively to use these inputs.

One further point needs to be discussed. In societies which are basically agrarian in nature, social status and political power often stem from the ownership of land. Thus, in those societies where this is true and in which land is distributed in an extreme fashion, one would expect political power and social status to be distributed in a very similar manner. It follows then that in these particular countries those who own the land would be able to exert the most influence over credit and educational institutions and organizations governing the distribution of capital. In other words, large landowners are likely to be able to purchase capital, in particular machinery, at prices which are lower than what the small landowner or tenant farmer would have to pay.

Empirical evidence concerning the availability and price of these external inputs to small and large farmers is difficult to find. However, there are a few studies which support the conclusion presented above. For example, Keith Griffin gathered data from a study of sixteen farmers in South Sulawesi, Indonesia concerning interest rates. The data seemed to show interest...
rates falling as farm size increased. In a study of Mexican agriculture, Tuckman found that the high income, large farm states of Northern Mexico used larger amounts of credit per hectare than the states characterized by small subsistence farms. Evidence on the relative availability and price of irrigation and education between large and small farmers is equally difficult to find, but what is available does tend to support the argument.

The greater access to credit and other inputs possessed by large farmers, relative to small, should enable them to make use of technologies which require the skilled application of large amounts of capital, most importantly machinery, relative to labour inputs. This follows from the fact that the privileged access to sources of credit allows the large farmer to purchase fertilizers, pesticides, and most importantly tractors at lower prices than small farmers and that the large farmer’s privileged access to educational institutions allows him to combine these in a very productive manner. The reverse holds for the small farmer, his lack of access to credit and education requires him to use techniques of production which are relatively simple and involve minimal amounts of capital relative to labour.

The ideas presented in the previous few paragraphs can be analysed with the Hayami-Ruttan inducement model outlined above if the model is modified. If the reader will remember, in this model the farmers were assumed to press public and private research firms for innovations which would allow them to save on the scarce factor of production. In their model, all farmers would be in the same position with respect to relative factor scarcity and would therefore be pressing research institutions to develop techniques to save a factor of production which they all felt was in scarce supply. However, the arguments presented in the previous paragraph would lead one to believe that there is likely to be a difference of opinion as to relative factor scarcities, with large farmers pressing research institutions for capital-using technology and small farmers pressing for labour-using technology.

Since political power and social status in a rural society many times tend to stem from the ownership of land, one would expect that often the interests of the large farmers would determine the direction of research into technological development. Thus, in this situation innovations developed by research institutions in the less developed nations, or those developed in advanced nations and modified to fit the climatic conditions in poor countries, will tend to involve the use of great amounts of capital, in particular machinery, relative to labour.

A good example of the innovation process being biased in the labour-saving, capital-using direction is provided by the experience of Argentina.

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In the 1930s cereal crop yields in Argentina were equal to those in the United States. If the reader will remember, it was during the 1930s that the United States began developing high yield seed varieties. However, Alain de Janvry has shown that in Argentina the lack of economic interest in yield-increasing technology by the larger farmers has been a major factor in the lag in the development of agricultural research institutions capable of generating yield-increasing biochemical technologies suited to the factor endowments of the majority of small and medium farms. Instead, technological development was biased strongly towards mechanical techniques which were more labour-saving than consistent with factor endowments. As a result, Argentina's export performance in cereal crops has suffered greatly.  

The obvious solution to this type of problem is, of course, land reform. In this way the interests of large landowners would no longer affect the development of technology. However, it is obvious that this course of action is not politically feasible. As an alternative, the government might seek to organize small farmers and rural labourers into regional associations. These associations would attempt to make the problems of the small farmer known to the existing research institutions and thus offset the influence of large landowners. In this manner innovations more suitable to a labour abundant nation would result and such a nation would thus be able to reduce their imports or expand their exports of staple food commodities.

IV

In this paper it was shown that world trade in staple food commodities is becoming increasingly dominated by the developed countries. Thus, the export share of the less developed countries has declined. This has been mainly due to problems on the supply side. Much of the research into biochemical technology takes place in the developed countries or in international research centres. The technologies developed are generally successful in the soils and climatic conditions existing in the region within which the research takes place. Thus, if the less developed nations borrow these technologies directly, it is obvious that the increase in productivity, reduction in the cost of production, is going to be less for them as compared to the developed country or region.

Even if the technologies could be directly borrowed and applied by the less developed countries with no reduction in the increase in productivity occurring as a result of differences in soil and climate, problems would still arise. Relative input costs are greatly different in the less developed relative to the developed countries. Specifically, the cost of fertilizer is higher in the former relative to the latter. As a result, the costs of production would fall more rapidly in the developed relative to the less developed countries.

Finally, in many less developed countries the ownership of land is unequally distributed. In addition, the large landowners are able to gain

access to capital, in particular machinery, at artificially low prices. As a result, they have a direct interest in the development of mechanical innovations which are not generally yield-increasing in nature. Thus, costs of production would tend to fall in the developed countries, developing biochemical technologies, relative to the less developed countries.

There are three basic policy implications. First, the less developed nations must allocate larger amounts of resources to agricultural research. This research should be directed towards developing techniques that are adapted to the soils, climate, and relative factor supplies of the particular nation under analysis. Second, fertilizer and other complementary inputs must be made available to the farmer at as low a price as is consistent with social opportunity costs. This implies that transportation systems and extension services should be improved. It also implies that if fertilizer can be cheaply produced elsewhere, it should be imported rather than using more costly domestic sources. Finally, the influence of larger landowners on the research process must be reduced. This could be achieved by organizing small farmers into regional organizations through which their problems and needs could be conveyed to research institutions.