Technological Change and Agricultural Trade Patterns

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An international trade model which explains trade patterns of processed foods relative to textiles using relative technological change and relative factor endowments was developed. This model was tested in the case of the United States and a number of ASEAN countries.

Results indicate that exogenous technology drives the trade patterns of the Asian Newly Industrializing Countries (NICs) while endogenous technology drives the trade patterns of the lesser developed ASEAN countries. Significant determinants of endogenous technology were identified: foreign aid flows, research and development expenditures, and market power. Two significant issues were raised in the course of the analysis: (1) the effectiveness of U.S. foreign aid package in developing the United States and the ASEAN countries' agri-based manufacturing industries, and (2) the evolution of the high growth Asian NICs and their impact on the lesser developed ASEAN countries.

Key words: technological change, international trade patterns, factor endowments, processed foods, ASEAN countries

Introduction

The impact of technological change on a country's international trade patterns is well recognized. Although significant progress has been made in the exploration of this area, analysis has been constrained by two major difficulties: inadequate data measuring technological change, and problems with the broad theoretical framework representing the characteristics of such activities and their impact on the economy. More specifically, most of the investigations that have been conducted on this topic were based on the limiting assumption that technology is exogenously determined, and have narrowly focused on the general manufacturing sector. In addition, most works on technology-based trade have dealt exclusively with U.S. trade--a significant drawback in testing technology-based trade theories since these theories seem to have originated with U.S. observations in the first place (Deardorf 1985).

This study aims to fill part of this gap by analyzing the relationship between endogenous technology and international trade of the United States and a group of less developed countries of Southeast Asia in their respective agri-based manufacturing sectors. It also tests the significance of hypothesized determinants of, and the direction of their effects on, the endogenization process of technological change in each country.

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Previous Research on Technology and International Trade

Posner (1961) suggested that innovating countries may export goods in which they may not even possess comparative advantage in terms of factor intensities and endowments. His model was adopted by Freeman (1963) who demonstrated that the location of production and exports were a function of technical progress. Posner's theory was formalized by Krugman (1979) who put it in the context of a Ricardian model with a continuum of goods. In 1979, Jones developed a neoclassical model which allows changes in technology to impact trade patterns. Although his model treats technology as exogenous, he did not rule out the existence of mechanisms which may induce technological progress.

One of the few economists who analyzed agricultural trade of countries other than the United States was Arnade (1992) who developed an empirical model that tested the relevance of factor endowments and exogenous technology in determining the agricultural trade patterns of Latin America. He concluded that both relative factor abundance and differences in technology explained Latin America's agricultural trading patterns.

Endogenization of Technology

Technology transfer and innovation are two inducement mechanisms believed to drive technological change. Technology transfer may result from purchases of capital goods, direct foreign investment, turnkey projects, or technical assistance and cooperation (Kakazu

1989). Likewise, many people consider foreign aid as a major avenue of technology transfer since most of the aid programs are coupled with technical assistance and support from the donor countries. The innovative process, on the other hand, requires an increasing share of research and development (R&D) expenditures (Kakazu 1989; Jensen and Thursby 1987; Gruber, et al. 1967). Another possible driving force behind innovations is market power. Kamien and Schwartz (1982) presented the Schumpeterian position that innovation is a result of R&D races among large firms. While the controversy about the direction of causality between innovative efforts and market power remains unresolved, the Schumpeterian hypothesis provides strong support to those who believe that market power encourages innovation rather than innovation resulting in increased market power.

The Endogenous Technology-based Trade Model

This study follows the approach by Arnade who regressed relative exports of capital-intensive to labor-intensive agricultural crops on measures of relative factor supplies and relative technological indices. However, this investigation considers the possibility that technological change may be endogenous and tests the model not only in the U.S. case, but also in the case of two groups of lesser developed country-members of the Association of Southeast Asian Nations (ASEAN): the Asian Newly Industrializing Countries (NICs) composed of Hong Kong, South Korea, and Singapore, and the less developed ASEAN countries (herein referred to as ASEAN LDCs) composed of Indonesia, Malaysia, and the Philippines for the period 1970-1990. In this study, the capital-intensive agri-based manufactured good is represented by processed foods while the labor-intensive agri-based manufactured good is represented by textiles.

The general specification of the recursive system of equations is given by:

$$[1]\quad RTECH_{ct} = \alpha_0 + \alpha_1 FAID_{ct} + \alpha_2 DFI_{ct} + \alpha_3 RD_{ct} + \alpha_4 RELMP_{ct} + \epsilon_1$$

$$[2]\quad RELEX_{ct} = \beta_0 + \beta_1 RFA_{ct} + \beta_2 RTECH_{ct} + \epsilon_2$$

where:

$RTECH_{ct}$ = the relative technological change parameter in the processed foods and textiles industries;

$FAID_{ct}$ = flow of foreign aid into the manufacturing sector of country c during time period t (in US$ million). In the case of the United States, this variable represents *outflow* of foreign aid funds directed to the recipient countries' manufacturing sector;

DFI_{ct} = inflow of direct foreign investments in the manufacturing sector of country c during time period t (in US$ million)

RD_{ct} = research and development expenditures in the manufacturing sector of country c during time period t (in US$ million)

$RELMP_{ct}$ = relative market power between the processed foods and the textiles industries in country c during time period t, computed as follows:

$$RELMP = \frac{market\ power\ (food)}{market\ power\ (textiles)}$$

where:

market power in the respective industries is measured as the reciprocal of the number of factories per 10,000 persons in the country's population;

RA_{ct} = ratio of total stock of capital to total stock of labor in the food processing and textiles industries;

$RELEX_{ct}$ = ratio of country c's exports of processed foods to textiles during time period t; and

c indexes country, and t indexes time period (year).

Since this study involves pooling cross-section and time-series observations, dummy variables were added to identify countries and years.

Relative Technological Change

Relative technological change (RELTECH) was measured using the ratio of the capital-intensive industry's (i.e., processed food) two-factor productivity index to the labor-intensive industry's (i.e., textiles) two-factor productivity index.

An industry's two-factor productivity index (TFPI) was calculated using Ball's formulation of the Tornqvist index (Ball 1984) as follows:

$$\ln(TFP_t/TFP_{t-1}) = \ln(Y_{i,t} + Y_{i,t-1}) - \tfrac{1}{2}\Sigma_i(s_{i,t} + s_{i,t-1})\ln(X_{i,t} + X_{i,t-1})$$

where the Y_is are commodity outputs, the X_is are input indices, and the s_is are input cost shares.

In measuring the aggregate input index, a weighted average of labor and capital services was calculated. The cost of labor was represented by the prevailing average manufacturing wage rates in the respective countries in time t.

Table 1
Regression Results of Endogenizing Technology
In Agri-based Manufactures

	U.S.A.	Asian NICs	Non-NIC ASEAN
	Parameter Estimates	Parameter Estimates	Parameter Estimates
Intercept	0.99 (0.43)	0.79 (0.37)	0.88 (0.04)
FAID	0.01* (0.002)	-0.08 (0.15)	-0.07* (0.03)
DFI	0.003 (0.0003)	0.01 (0.02)	-0.03 (0.02)
RD	-0.26 (0.28)	0.27 (0.38)	-0.04* (0.02)
RELMP	0.11 (0.23)	-0.05 (0.06)	0.67* (0.13)
	R^2 = 0.51 n = 17 F = 3.09 Pr>F = 0.06	R^2 = 0.05 n = 60 F = 0.48 Pr>F = 0.82	R^2 = 0.53 n = 52 F = 8.37 Pr>F = 0.0001

Figures in parentheses are standard errors.
* = coefficient is significant at the 10% level
n.a. = not applicable

Empirical Results

Endogenization of Technology

Results of endogenizing technology are presented in Table 1. The specifications were tested for potential collinearity, autocorrelation, and heteroskedasticity problems and were found to be free of each problem at the 10 percent level.

As suggested by the R^2 and F values, the model appears to fit the data well in the case of the United States and the ASEAN LDCs, but not in the case of the Asian NICs. In addition, no technology-endogenizing variable was found to be significant in the case of the Asian NICs, suggesting that technological progress in this group of countries is exogenous. Only the FAID variable was significant in the U.S. case, while three variables were significant in the ASEAN LDCs: FAID, RD, and RELMP. These findings suggest that relative technological progress in the agri-based manufacturing sector of the ASEAN LDCs is driven by both technology transfer and innovation, whereas relative technological progress in the United States is driven only by technology transfer.

The significant positive coefficient of FAID in the United States (i.e., *outflows* of foreign aid from the United States) indicates that as the United States increases its foreign aid outflows, the productivity of its food sector relative to its textile sector increases. This may imply that either technological progress in the U.S. processed foods sector is more positively responsive to outflows of U.S. foreign aid or technological progress in the U.S. textiles industry is more negatively sensitive to foreign aid outflows.

Table 2
Regression Results:
The Effects of Relative Factor Endowments
And Relative Endogenous Technical Change
On Trade Patterns of Agri-based Manufactures

	U.S.A.	Asian NICs	Non-NIC ASEAN
	Parameter Estimates	Parameter Estimates (Exogenous Technology)	Parameter Estimates
Intercept	3.97 (2.58)	-0.13 (0.10)	10.98 (11.07)
RFA	-0.0001 (0.0002)	-23.83 (40.17)	9197.13 (2987.79)
RTECH	-1.45 (2.63)	0.19 (0.10)	16.51 (11.92)
	R^2 = 0.11 n = 18 F = 0.89 Pr>F = 0.43	R^2 = 0.94 n = 44 F = 156.83 Pr>F = 0.0001	R^2 = 0.43 n = 37 F = 5.98 Pr>F = 0.001

Figures in parentheses are standard errors.
* = coefficient is significant at the 10% level

The significant negative coefficient of FAID in the ASEAN LDCs indicates that as the amount of foreign aid flowing into the ASEAN LDCs increases, the technological level of the food industry tends to lag behind that of textiles. This relationship indicates a strong possibility that the major portion of aid money that these countries receive is channeled into or has spillover impacts on the development of the textile industry rather than their food sector.

The negative sign of the RD coefficient implies that as the amount of R&D spending in the manufacturing sector increases, technological development in the food industry tends to lag behind that of textiles. This may also indicate a strong possibility that a more significant portion of R&D spending is channeled toward the textiles industry at the expense of the food processing industry. A more comprehendible result is suggested by the significant positive RELMP coefficient which suggests that as the market power in the food processing industry increases relative to that in the textiles industry, the former's technological level tends to surpass that of the latter. This relationship illustrates a case where market power or concentration is associated with a greater degree of technological advancement, consistent with the Schumpeterian hypothesis.

The negative coefficient of DFI, although not significant at the 10 percent level, presents an interesting connotation. That is, as the volume of foreign direct investment inflows in the manufacturing sector increases, the relative technological progress in the food processing industry tends to diminish vis-a-vis the textiles industry.

Relative Technology, Factor Endowments, and Trade Patterns

Results of regressing relative export against endogenous technological progress index and relative factor abundance in the United States and the ASEAN LDCs are presented in Table 2. Similarly, Table 2 presents the results of regressing relative export against exogenous technological progress index and relative factor abundance in the Asian NICs.

In the case of the United States, the R^2 and F values indicate a poor fit of the model. In addition, both factor endowments and technology variables were found to be non-significant at the 10 percent level.

In the case of the ASEAN LDCs, the significant positive RFA coefficient indicates that the Hecksher-Ohlin Theory holds, as expected a priori.

Although the RTECH coefficient is not significant at the 10 percent level, it has a p-value of 0.176 which provides strong justification to consider discussing its impact on relative exports. A positive sign of the RTECH coefficient in this case indicates that international trade patterns are positively related with technological progress. Thus, results of this study provide strong support to the authors' thesis that factor endowments and technological progress may simultaneously affect trade patterns.

In the case of the Asian NICs where exogenous technology variable was used as a regressor, results indicate that exogenous technology has significant impact on a country's trade patterns, as verified in previous studies.

Developments in the Asian Region

The development experience of Asia in the last decade is characterized by countries pursuing widely divergent strategies and policies resulting in diverse growth performance. The natural resource-poor Newly Industrializing Countries (NICs), namely Hong Kong, South Korea, and Singapore, with their outward-looking export-oriented strategies, have recorded high growth rates. In contrast, the natural resource-rich countries of Indonesia, Malaysia, and the Philippines have had various experiences typical of lesser developed economies.

The finding that the FAID and DFI coefficients are both negative runs counter to a priori expectations. However, recent developments in the Asian economy present some enlightening explanations to these relationships. For instance, currency appreciation, coupled with rising labor costs, has induced the NICs to transfer their industries, especially those that are labor-intensive, to the lesser developed Asian countries where wage rates are significantly lower. Thus, with the inflows of direct foreign investments mostly allocated in the labor-intensive industry, the relative technological progress of the capital-intensive to labor-intensive industries decreases in the less developed ASEAN countries.

In the same manner, as the NICs increase their investment in the LDCs, the number of factories that are set up in the labor-intensive industry increases relative to that in the capital-intensive industry. This drives up the number of factories in the labor-intensive industry, creating a more competitive setting in this industry relative to the capital-intensive industry, and shows up as an increase in the relative market power of the latter industry against the former. This results in an increase in relative technological progress in the capital-intensive industry and may provide an explanation for the positive sign of RELMP.

This finding also provides support to the Schumpeterian hypothesis that market power provides incentive to technological development. Such ramifications would be more credible, however, if the RD coefficient turned out to be positively signed, since that would have implied that innovation (as proxied by R&D expenditures) drives technological progress. Since larger firms tend to have a greater motivation to innovate, then a positive RD coefficient would have provided a stronger support for the Schumpeterian hypothesis. However, one should realize that the RD used in this study does not represent a ratio variable--a condition that limits our analytical capacity.

Conclusions

This paper has tested an alternative model that explains trade patterns based on the Heckscher-Ohlin model and endogenous technological influences. The basic feature of this model is the determination of variables which influence relative technological progress in the agri-based manufactured goods sectors of the United States and the less developed economies in Southeast Asia.

Results indicate that the agri-based manufactured goods sector exhibits endogenous technology-driven trade patterns between the capital-intensive industry (processed foods) and the labor-intensive industry (textiles). Such technological changes were found to be associated with both technology transfer mechanisms (e.g., foreign aid) and innovations driven by R&D and market power.

Considering that the United States experiences an endogenously driven technological impact on its trade pattern while the relatively lesser developed Asian NICs experience exogenous technology effect on their trade patterns highlights the strong possibility of the existence of the Product Cycle (PC). In this interpretation, the United States represents the high-technology,

innovating country whereas the lesser developed Asian NICs represent the followers/laggards who eventually catch up with the innovator (i.e., the United States) and consequently effect significant changes in their patterns of trade. This suggests a need for national policy makers to be more marketing management-oriented in the process of policy formulation in order to successfully apply the PC concept to the producers' and the exporters' advantage.

An interesting result lies in the close similarity between the United States and the ASEAN LDCs, particularly in the significance of both their FAID variable, and the similar signs of their respective RD and RELMP coefficients. These results basically imply that both the United States and the ASEAN LDCs experience relative technological development driven by technology transfer (as manifested by the significant FAID). In addition, the ASEAN LDCs experience relative technological progress driven by innovation, through research and development, and market power.

Results also provide strong support to the hypothesis that both factor endowments and technology could simultaneously drive trade patterns.

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